U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-293 355

Oxidation Ditch Treatment of Meatpacking Wastes

John Morrell and Co, Chicago, IL

Prepared for

Industrial Environmental Research Lab -Cincinnati, OH

Jan 79

United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-79-030
January 1979

Research and Development

PB 293355

EPA

Oxidation Ditch Treatment of Meatpacking Wastes

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the ENVIRONMENTAL PROTECTION TECHNOLOGY series. This series describes research performed to develop and demonstrate instrumentation, equipment, and methodology to repair or prevent environmental degradation from point and non-point sources of pollution. This work provides the new or improved technology required for the control and treatment of pollution sources to meet environmental quality standards.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/2-79-030	2.
3. RECIPIENT'S ACCESSION NO. PB293355	
4. TITLE AND SUBTITLE OXIDATION DITCH TREATMENT OF MEATPACKING WASTES	5. REPORT DATE January 1979 issuing date
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Wayne L. Paulson and Lawrence D. Lively	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS John Morrell and Company Chicago, Illinois 60604	10. PROGRAM ELEMENT NO. 1BB610
	11. CONTRACT/GRANT NO. 12060 EUB
12. SPONSORING AGENCY NAME AND ADDRESS Industrial Environmental Research Lab. - Cinn, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED Technical 1966-1972
	14. SPONSORING AGENCY CODE EPA/600/12
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

The analysis of 18 months of early operation for a channel aeration activated sludge wastewater treatment plant is presented. The treatment plant receives an average flow of 2.8 million gallons per day from the John Morrell and Company, Ottumwa, Iowa hog and beef meatpacking plant. The treatment plant includes pre-aeration, primary settling and grease removal followed by two 3.5 million gallon aeration channels (40 by 6 feet deep by 1,050 feet in length) in parallel. Rotor and floating aerators are utilized. One channel utilizes an experimental straightline settling unit (16 by 475 by 6 feet deep).

The design and operation of the primary treatment units was inadequate. Tubular conveyors for sludge removal were not satisfactory. More efficient grease and suspended solids removal is needed prior to the aeration process. The channel aeration activated sludge process is capable of achieving organic removals of 90 to 95 percent from meatpacking wastewater. High effluent ammonia levels are of concern. Various plant design changes are needed to improve the consistency of good effluent quality. Protection and proper location of mechanical equipment, i.e., rotor aerators, is necessary in northern climates to minimize icing problems.

Dewatered waste activated sludge from meatpacking waste treatment appears to have potential as an animal feed supplement.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Food processing Wastewater Treatment Sludge	Meatpacking Wastes, Oxidation Ditch	13/B

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 123
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE A06-A01

EPA Form 2220-1 (9-73)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979-657-060/1600

EPA-600/2-79-030
January 1979

OXIDATION DITCH TREATMENT OF MEATPACKING WASTES

by

Wayne L. Paulson
Lawrence D. Lively
John Morrell and Company
Chicago, Illinois 60604

Grant No. 12060 EUB

Project Officer

Jack L. Witherow
Food and Wood Products Branch
Industrial Environmental Research Laboratory
Cincinnati, Ohio 45268

INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

ia

DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory - Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-Ci) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report presents design, modification, and evaluation of a channel aeration activated sludge wastewater treatment plant, which treated 2.8 million gallons per day of wastewater from a large meatpacking operation. Design engineers and managers of industrial plants discharging wastewaters with high concentrations of organic pollutants will find the report valuable when selecting, designing, and operating an activated sludge treatment process. Further information on the subject can be obtained by contacting the Food and Wood Products Branch, Industrial Environmental Research Laboratory-Cincinnati.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

The analysis of 18 months of operation for a channel aeration activated sludge wastewater treatment plant is presented. The treatment plan receives an average flow of 2.8 million gallons per day from the John Morrell and Company, Ottumwa, Iowa, hog and beef meatpacking plant. The treatment plant includes pre-aeration, primary settling, and grease removal followed by two 3.5-million gallon aeration channels (40 by 6 feet deep by 1,050 feet in length) in parallel. Rotor and floating aerators are utilized. One channel utilizes an experimental straightline settling unit (16 by 475 by 6 feet deep). The other uses a rim-flow 58 feet in diameter circular settling unit.

The design and operation of the primary treatment units were inadequate, especially the tubular conveyors used for sludge removal. More efficient grease and suspended solids removal are needed before the aeration process.

The channel aeration activated sludge process is capable of achieving BOD removal of 90 to 95 percent from meatpacking wastewater. High effluent ammonia levels (approximately 20 milligrams per liter) are of concern. Various design changes are needed to improve the consistency of high effluent quality.

Dewatered waste-activated sludge from meatpacking waste treatment has potential as an animal feed supplement.

This report was submitted in fulfillment of Project No. 12060 EUB by the John Morrell and Company under the partial sponsorhip of the US Environmental Protection Agency. The report covers the period December 1966 to July 1972, and work was completed as of July 1972.

CONTENTS

Foreword iii
Abstract iv
Figures vi
Tables ix
Conversion Factors xi
Acknowledgments xii

1. Introduction 1
   Scope and background 1
   Design Approach 1
2. Conclusions 4
3. Recommendations 6
4. Process Description 7
   Flow pattern 7
   Primary units 7
   Secondary units 12
5. Operational Experience - Mechanical 14
   Plant interrelationships 14
   Primary units - aeration, flotation, settling 14
   Aeration channels 15
   Straightline settling unit 16
6. Process Evaluation 18
   Project objectives 18
   Sampling and analytical program 18
   Wastewater characteristics 19
7. Primary Treatment Performance 23
   Removal of organics and solids 23
   Solids and grease disposal 29
   Pilot plant study - dissolved air flotation 30
8. Secondary Treatment Performance 32
   East channel (I) - circular settler 32
   West channel (II) - straightline settler 46
   Aeration system analysis 59
9. Financial Considerations 61
   Construction costs 61
   Operation and maintenance costs 61
   Total annual costs 61
10. Waste Activated Sludge Utilization 65
   Characteristics and treatment 65
   Animal feed supplement 65
11. Effluent Chlorination 72
12. Pertinent Publications 74

Appendices 75

FIGURES

Number		Page
1	Typical wastewater flows	8
2	Schematic flow diagram	9
3	Wastewater treatment system	10
4	Live weight kill versus date	21
5	Total flow versus date	22
6	Percent removal suspended solids (primary) versus flow	26
7	Percent removal grease (primary) versus flow	27
8	Percent removal BOD (primary) versus flow	28
9	East channel flow versus date	34
10	East channel dissolved oxygen versus date	35
11	East channel temperature versus date	36
12	East channel MLSS versus date	37
13	Sludge volume index versus date (east)	41
14	Sludge volume index versus effluent suspended solids (east)	42
15	Flow rate versus effluent suspended solids (east)	43
16	Volumetric loading versus percent removal BOD (east)	44
17	Loading factor versus percent removal BOD (east)	45
18	West channel flow versus date	48
19	West channel dissolved oxygen versus date	49
20	West channel MLSS versus date	50
21	Sludge volume index versus date (west)	53

Figures (continued)

Number		Page
22	Sludge volume index versus effluent suspended solids (west) . .	54
23	Flow rate versus effluent suspended solids (west)	56
24	Volumetric loading versus removal BOD (west)	57
25	Loading factor versus percent removal BOD (west)	58
A-1	Pounds suspended solids/live weight killed versus date (raw) . .	75
A-2	Raw total suspended solids versus primary effluent total suspended solids	76
A-3	Percent removal suspended solids versus date (primary)	77
A-4	Raw grease versus primary effluent grease	78
A-5	Raw BOD versus primary effluent BOD	79
B-1	East effluent suspended solids versus date	80
B-2	East effluent pounds suspended solids/live weight killed versus date	81
B-3	East effluent BOD total versus date	82
B-4	East effluent pounds BOD total/live weight killed versus date .	83
C-1	West effluent suspended solids versus date	84
C-2	West effluent pounds suspended solids/live weight killed versus date	85
C-3	West effluent BOD total versus date	86
C-4	West effluent pounds BOD total/live weight killed versus date .	87
D-1	Plant site location	88
D-2	Aerial view of treatment system in construction	89
D-3	Treatment plant	90
D-4	Heating unit modification to tubular conveyor system	91
D-5	Pre-aeration primary unit and composite sampler	92
D-6	Tubular conveyors in primary system	93

Figures (continued)

Number		Page
D-7	Grease wagons and solids disposal carts	94
D-8	Rotor and floating aerators in west channel	95
D-9	Fifty-horsepower floating aerator	96
D-10	Drum failure of 50-horsepower floating aerator	97
D-11	Typical blades of rotor aerator	98
D-12	Close-up of rotor aerator operation - east channel	99
D-13	Icing problems with rotor aerators and walkway	100
D-14	Initial flat shield design for icing conditions	101
D-15	Icing problems and motor covers - rotor aerators	102
D-16	Curved shield system to minimize icing	103
D-17	Inlet and sludge collector area for straightline settler	104
D-18	Side inlet port to straightline settler	105
D-19	Straightline settler and cage rotor - drained	106
D-20	Straightline settler in operation	107
D-21	Effluent weir for straightline settler	108
D-22	Turbulence and flushing door location - straightline settler	109
D-23	Circular settling unit - east channel	110

TABLES

Number		Page
1	Plant Features	11
2	Detention Time and Overflow Rate	16
3	Characteristics of Wastewater Flow	20
4	Performance of Primary Units	24
5	Settling Unit Detention Time and Overflow Rate	24
6	Primary Effluent Characteristics	25
7	Grit Quantities and Characteristics	29
8	Primary Sludge Characteristics	30
9	Performance of DAF Unit	31
10	Operational Characteristics - East Aeration Channel (I)	33
11	Final Effluent Characteristics - East Aeration Channel (I)	38
12	Performance of Secondary Units - East Channel (I)	39
13	Circular Clarifier Detention Time and Overflow Rate	40
14	Operational Characteristics - West Aeration Channel (II)	47
15	Final Effluent Characteristics - West Aeration Channel (II)	51
16	Performance of Secondary Units - West Channel (II)	52
17	Detention Time and Overflow Rate for Straightline Settler	55
18	Construction and Equipment Costs	62
19	Operation and Maintenance Costs - 1971	63
20	Power Requirements	63
21	Treatment Costs	64

Tables (continued)

Number		Page
22	Basket Centrifugation of Waste Activated Sludge	66
23	Composition of Waste Activated Sludge	67
24	Protein Evaluation Tests	68
25	Composition of Sludge	68
26	Rat Feeding Test	70
27	Amino Acid Analysis of Activated Sludge	71
28	Typical Coliform Results	72
29	Final Effluent Chlorination	73

CONVERSION FACTORS AND METRIC PREFIXES[a]

CONVERSION FACTORS

To convert from	To	Multiply by
Degree Celsius (^oC)	Degree Fahrenheit	$t_F^o = 1.8\ t_C^o + 32$
Cubic Feet	$Metre^3$	2.831×10^{-2}
Foot	Metre	3.048×10^{-1}
Square feet	$Metre^3$	9.290×10^{-4}
$Feet^3/min$	$Metre^3/sec$	4.719×10^{-4}
Gallon	$Metre^3$	3.785×10^{-3}
Gallon/day	$Metre^3/sec$	4.381×10^{-8}
Horsepower	Watt	7.457×10^{2}
Inch	Metre	2.540×10^{-2}
Pounds	Kilograms	4.535×10^{-1}

METRIC PREFIXES

Prefix	Symbol	Multiplication factor	Example
Giga	G	10^9	1 GJ - 1 x 10^9 joules
Kilo	k	10^3	1 kg - 1 x 10^3 grams
Mega	M	10^6	1 MJ = 1 x 10^6 joules
Milli	m	10^{-3}	1 mm = 1 x 10^{-3} meter

[a]Standard for Metric Practice. ANSI/ASTM Designation: E 380-76 , IEE std 268-1976, American Society for Testing and Materials, Philadelphia, Pennsylvania, February 1976. 37 pp.

ACKNOWLEDGMENTS

During the course of this project, many individuals contributed to its successful completion.

Dr. H. O. Halverson conceived the original application of the process to treatment of meatpacking wastes. His concepts were further developed by Mr. George Ahrens, John Morrell Project Engineer, with assistance from the Mechanical Engineering Department of John Morrell and Company and US Environmental Protection Agency engineers.

Mr. Darwin Kueck performed admirably as Project Director through the trying times of start-up to the research demonstration phase. His close attention to solution of mechanical difficulties and coordination of in-plant waste management is particularly noteworthy. Mr. Anthony Grenis and Mr. Paul Lange performed the chemical analysis required for the project study.

Special recognition is tendered Dr. William E. Kramlich, Vice President and Director of Research, John Morrell and Company, for his direction, encouragement, and resourcefulness.

The assistance and encouragement of Mr. Perry Martin, Plant Manager; Mr. Mike Link, Operations Manager; and Mr. John Logan, Master Mechanic was imperative to success of the project.

Special accolades are due Mrs. Carolyn Pierce for clerical, secretarial, and procurement support. Without the dedication and resourcefulness of Mr. Dale Wilson, Chief Operator of the Treatment Plant, completion of the project would have been prolonged. Recognition is also given Mr. Dale Baker, Plant Operator, for superior services.

Appreciation is extended to Mr. L. D. McMullen, University of Iowa, for providing computer analysis of the data and to Mrs. Lois Will for assistance in processing the data and preparation of the final report.

The support of the project by the Office of Research and Development, US Environmental Protection Agency is gratefully acknowledged. Particular appreciation is extended to Mr. Jack L. Witherow, Food and Wood Products Branch, Industrial Environmental Research Laboratory, Cincinnati and Mr. George Keeler, US Environmental Protection Agency, Washington, DC.

SECTION 1

INTRODUCTION

SCOPE AND BACKGROUND

The primary objective of this demonstration project was to determine the maximum effectiveness of the channel aeration activated sludge process in achieving biochemical oxygen demand (BOD) and nitrogen removal from packing-house wastewater. The project included design, construction, and operational phases. Additional objectives of the project were evaluation of the primary treatment unit performance and utilization of waste activated sludge as an animal feed supplement.

The project was located at the John Morrell and Company meatpacking plant in Ottumwa, Iowa. Morrell and Company located meatpacking operations in Ottumwa in 1887. The plant was nearly destroyed by fire in 1893. In the early 1900's, the facilities were rebuilt and expanded. Several of the buildings currently in use date back to this period. During the study period the plant employed approximately 2,600 people. The average daily live weight processed is 2 million pounds. This plant processes 6,500 to 7,000 hogs and 1,000 to 1,100 cattle per day in a one-shift operation, normally 5 days per week.

The plant is located in south central Iowa near the Des Moines River. This river basin drains central Iowa. A flood control reservoir (Redrock), upstream from Ottumwa, completed in 1969 is to provide a minimum stream flow of 300 cubic feet per second. River surveys were conducted by the State, Morrell personnel, and consultants in the 1940's. As a result of these findings, several in-plant control measures were begun in order to improve the quality of waste discharges. These measures and others were instituted during the 1950's and early 1960's. Daily losses of BOD, protein, and grease in pounds per 1,000 pounds of live weight were reduced from 35 to 15, 18 to 8, and 20 to 6, respectively. Some of the measures utilized to achieve this change are dry rendering, dry removal of beef paunch, installation of catch basins, and various separation and housekeeping techniques.

In 1966, the State of Iowa conducted a study of conditions in the Des Moines River and waste contributions from the Ottumwa area. Based on established Iowa water quality criteria for the Des Moines River downstream from Ottumwa, the State set an allowable BOD discharge for treated wastewater effluent from Morrell and Company of 2,200 pounds per day (see Figure D-1).

During 1966-1977, in-plant waste surveys were conducted at Morrell to determine the wastewater quantities and characteristics for treatment plant design. It was determined that from 3.25 to 3.50 million gallons of wastewater per day would require treatment. The daily (5-day week) BOD loading was predicted to be 38,000 pounds. Based on a flow rate of 3.25 to 3.50 million gallons per day, effluent quality (BOD) would have to be between 75 and 80 milligrams per liter. The overall treatment plant efficiency (BOD) required would be approximately 95 percent.

DESIGN APPROACH

Dr. H. O. Halvorson, consultant to Morrell, and the Morrell engineering and research staff investigated several meatpacking waste treatment methods that might be applied at Ottumwa. Dr. Halvorson recommended that the oxidation ditch activated sludge process be investigated for the Morrell plant. This process (known also as the Pasveer process) has been utilized extensively in western Europe in the 1950's and 1960's. More than 100 such plants have been installed in the United States and Canada.

Dr. Halvorson had observed the oxidation ditch process in Europe and had worked on similar plants in the United States. He also cited a study by F. Guillaume (Evaulation of the Oxidation Ditch as a Means of Wastewater Treatment in Ontario. Ontario Water Resources Commission. July 1964). Guillaume had concluded that "on the basis of the acquired information, that the oxidation ditch treatment system is rather inexpensive to construct and simple to operate, and that it produces an acceptable effluent consistently." This conclusion was made with small municipalities in mind as he further observed that an upper limit in size for which the oxidation ditch would still be preferable was not known.

Municipal oxidation ditch plant performance at Glenwood, Minnesota, and pilot plant studies on meatpacking wastes at Arkansas City, Kansas (Halvorson, H. V., et al. Report - Proposed Packinghouse Waste Treatment Plant Employing a Channel Aeration Process. John Morrell and Company. 1967), were used to provide design information. Overall BOD reductions from 61 to 92 percent were obtained at Arkansas City, with detention times from 8 to 48 hours and BOD loadings from 8 to 65 cubic feet of ditch per pound of BOD. Dr. Halvorson recommended a minimum detention time of 24 hours with a maximum BOD loading of 1 pound of BOD per 30 cubic feet of channel (33 pounds per 1,000 cubic feet). Additional design criteria were proposed based in part on the above plants. A federal research and demonstration grant was then obtained to partially support the project.

The original plant design by Halvorson, et al., was not approved initially by State officials. Various modifications were necessary prior to approval of plans for construction. The final plant design was developed by Mr. George E. Ahrens, Engineer and initial Project Director for Morrell and Company at Ottumwa, with the assistance and approval of Morrell and Company engineering staff and US Environmental Protection Agency research staff. The details of the plant design will be presented in a subsequent section.

Project bids were received in September 1968. The total plant cost was estimated at $780,000. Wastewater flow was first accepted in November 1969. Major mechanical and other plant start up difficulties developed and continued until the fall of 1970. The major portion of the process evaluation was conducted from January 1971 through June 1972.

SECTION 2

CONCLUSIONS

1. The channel aeration activated sludge process is capable of achieving BOD removal of 90 to 95 percent from meatpacking wastewater. High effluent ammonia levels (approximately 20 milligrams per liter as nitrogen) are of concern however.

   Given the solid-liquid separation problems and the aeration limitations, the overall treatment plant removal (untreated versus total east effluent) was 95.7 percent (BOD_5), 84.6 percent (suspended solids), and 96.3 percent for grease.

2. In order to achieve a more consistent effluent quality, improvements in pre-treatment, aeration capacity and final sedimentation are needed.

3. The peak flow to the treatment plant was normally sustained for approximately 12 hours each day with a peak to average flow rate ratio of 1.2:1.

4. The design and operation of the primary treatment units were inadequate. More efficient grease and suspended solids removal is needed prior to the aeration process. Primary treatment modifications could significantly increase the sludge collected and increase the potential for its use in a by-product.

5. Tubular conveyors of the size used in the primary treatment system are not satisfactory as sludge removal mechanisms for this type of application.

6. Protection and proper location of the walkways and mechanical equipment, i.e., rotor aerators, are necessary in northern climates to minimize icing problems.

7. The aeration capacity was insufficient to obtain nitrification. Ammonia concentrations were usually increased through the channel aeration activated sludge process. This increase was also significantly affected by the anaerobic sludge conditions in the primary treatment unit.

8. The mixed liquor suspended solids (MLSS) level was also limited by aeration capacity. Oxygen deficiencies and odor problems were observed at the higher levels of MLSS concentration.

9. The effluent suspended solids variations did not correlate with flow to the circular clarifier. The variations were largely due to the settling properties of the suspension.

10. The concept of utilizing an available interior channel has merit, however the performance of the unit was not successful because of the design of the inlet, outlet and sludge collection system in the channel.

11. Air flotation followed by centrifugation is a satisfactory method for concentration of the waste activated sludge. High recoveries and very high cake concentrations were achieved via centrifugation of settled waste activated sludge without the use of chemicals.

12. Dewatered waste activated sludge from meatpacking wastewater treatment has potential as an animal feed suplement.

13. A chlorine dosage in excess of 10 milligrams per liter and a contact time of approximately 15 minutes will achieve greater than 99 percent fecal coliform reductions. In practically all cases the chlorinated final effluent fecal coliform count was less than or equal to 10 organisms per 100 milliliters.

14. Total wastewater treatment costs for this treatment system, including estimated costs for solids disposal, would be approximately 2 cents per pound of BOD applied (33 cents per 1,000 pounds live weight killed, LWK).

SECTION 3

RECOMMENDATIONS

1. More efficient and consistent pre-treatment is needed for successful operation of the oxidation ditch activated sludge process for meat packing wastewater treatment.

   Consideration should be given to pressure air flotation or anaerobic systems as pre-treatment units.

2. In order to utilize the design concept of the straightline settling unit, improvements in the hydraulic design and solids removal features are needed.

3. More flexibility and capacity should be incorporated in aeration system design of this nature. The aeration system should have the ability to be operated to meet the daily load variations as well as adjust to non-production periods.

4. The potential of recovery of waste activated sludge for use as an animal feel supplement warrants further study.

5. The nitrogen balance aspects of meatpacking waste treatment needs careful study but this objective could not be fully accomplished in this investigation. The aeration capacity was not sufficient to obtain nitrification.

6. The evaluation of the potential for nitrification and possible denitrification in an oxidation ditch process should be undertaken at pilot scale to establish economic and technical feasibility.

7. Caution is required in experimenting with new equipment and process design at full scale without some prior developmental or pilot investigations. Experimentation with equipment should not be at the expense of affecting the intended process evaluation. Additional unit capacity to permit the experimentation without affecting the process study should be incorporated into the project.

SECTION 4

PROCESS DESCRIPTION

FLOW PATTERN

Initially, the wastewater treatment plant received flow from the hog and beef kill in-plant catch basins. Sanitary wastewater and condenser water is discharged to a separate 48-inch sewer line that is not normally tributary to the treatment plant. Some additional plant flow such as from the stockyard area and dehairing operations were added to the plant flow during the project. The meatpacking operations are normally on a 5-day week one-shift schedule. Typical weekday and weekend flow patterns are shown in Figure 1.

A schematic flow diagram of the plant design is shown in Figure 2. A plant drawing and unit listing is presented in Figure 3. A description of the plant features is shown in Table 1 (also see Figure D-2).

PRIMARY UNITS

The bar screen is hand-cleaned and receives the total gravity flow from the processing operations before it is pumped to the treatment units. Constant and variable speed pumps are used to match the in-flow to the treatment plant.

The aeration compartment is intended to serve the dual purpose of grit separation and aiding in grease separation. At design flow rate (3.25 million gallons per day), the aeration compartment provides a 12-minute contact time. The raw or untreated composite wastewater sample is taken at this point. The settling compartment or catch basin provides a 42-minute detention time at design flow. Tubular conveyors were installed to remove settleable solids and grit, and this is believed to be the first installation of this type. Collector flights convey the floated grease to the discharge end of the basin. An overhead skimmer moves the grease into a trough equipped with a screw auger for disposal to a grease hauling unit (see Figure D-5).

Primary sludge and grit is collected in 60-gallon dump carts and conveyed to a landfill for disposal. Grease is collected in trailer-mounted 2,000-gallon tanks for transport to the rendering department.

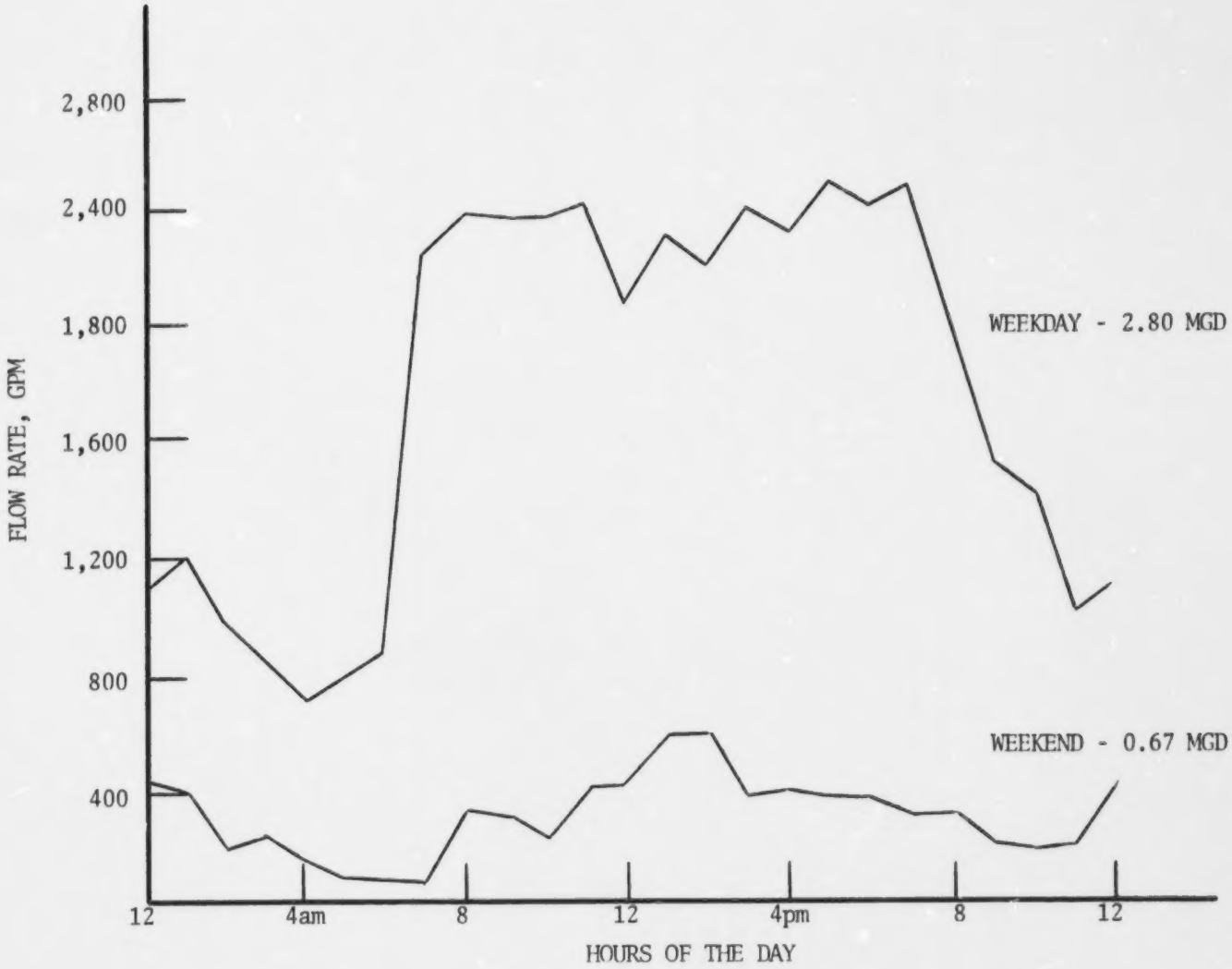

Figure 1. Typical wastewater flows.

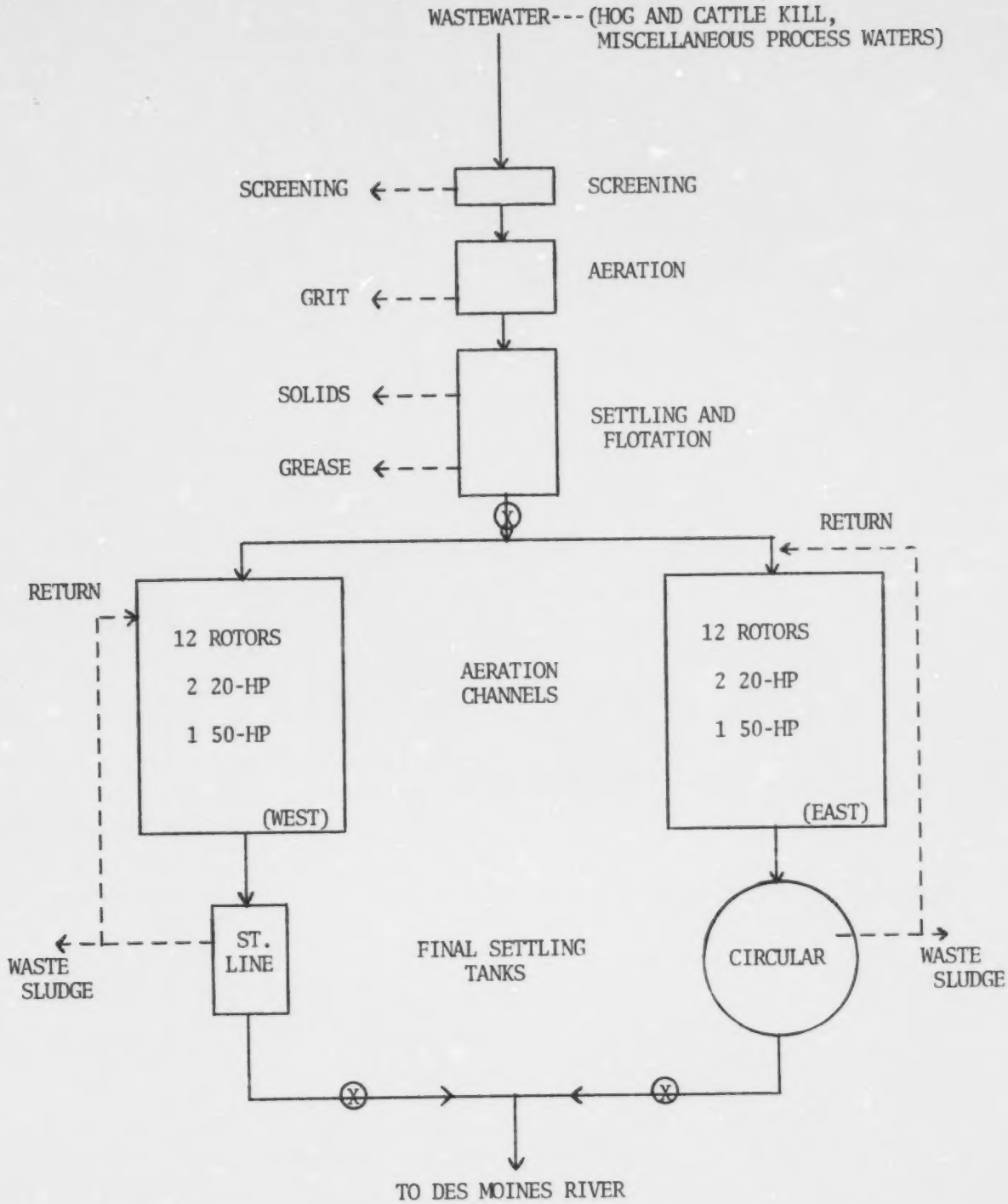

Figure 2. Schematic flow diagram.

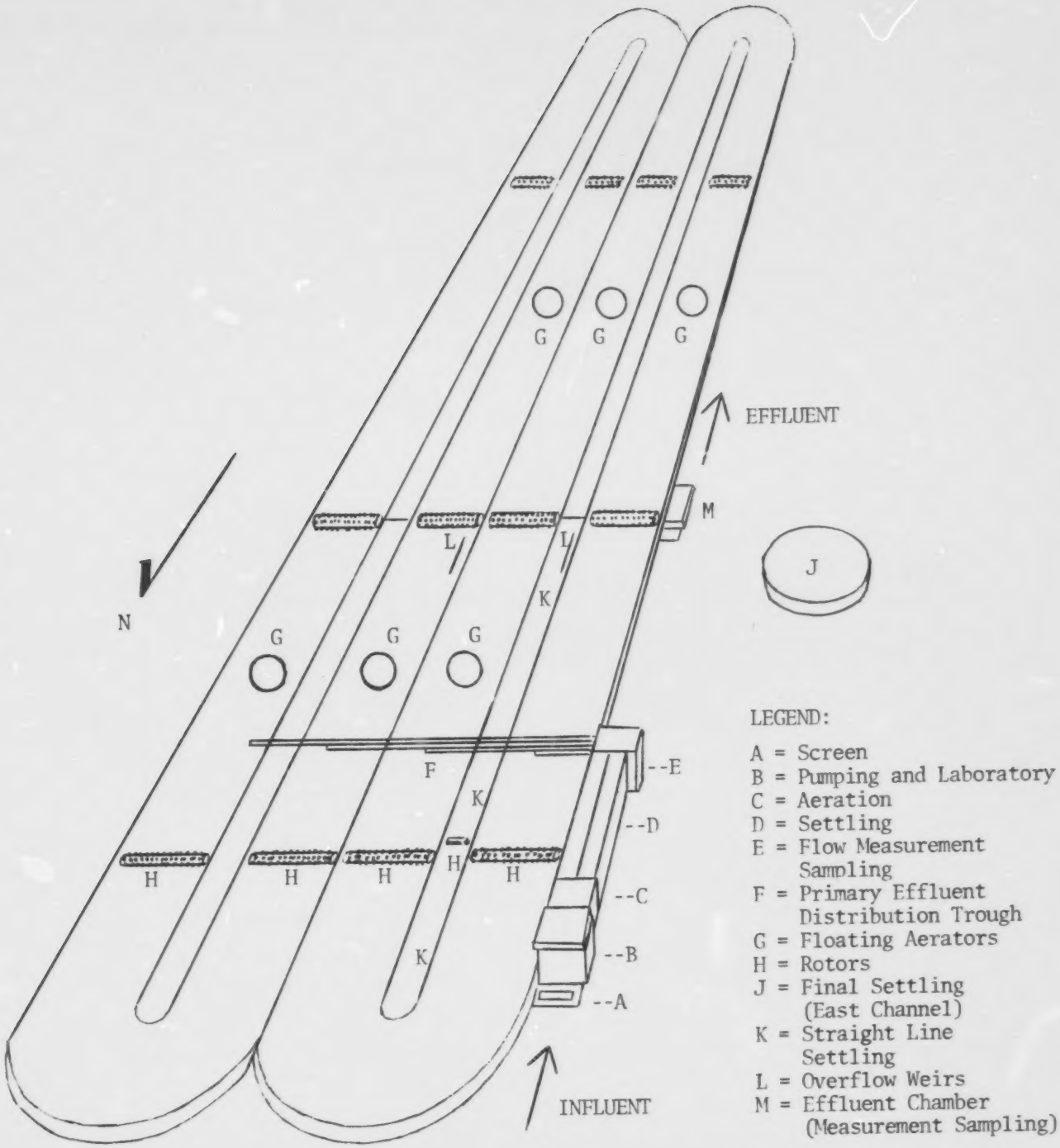

Figure 3. Wastewater treatment system.

TABLE 1. PLANT FEATURES

Item	Description
Bar screen	1.4 inch openings (size: 3' x 4')
Aeration compartment	21' x 20' x 9' (28,000 gallons) Air supply: 150 cubic feet per minute
Settling compartment (Grease flotation)	20' x 100' x 6½' (97,000 gallons)
Aeration channels*	40' wide; 6' water depth Length (N-S; st. line): 1,050' Volume (each channel): 3,500,000 gallons
Straightline settling unit	16' x 475' x 6' (342,000 gallons) Area: 7,600 square feet
Circular settling unit	58' diameter; 9' depth (178,000 gallons) Area (rim-flow): 2,640 square feet
Aeration equipment	East channel: 12 mini-magna rotors 27½" diameter; 15' length West channel: 12 magna rotors 42" diameter; 15' length Each channel: 2 20-horsepower and 1 50-horsepower floating aerators
Flow measurement	Parshall flumes and primary effluent: settled effluent from each channel
Composite samplers	Plant influent and primary effluent: settled effluent from each channel

*Guillaume, F. Evaluation of the Oxidation Ditch as a Means Wastewater Treatment in Ontario. Ontario Water Resources Commission, July 1964.

SECONDARY UNITS

The total primary effluent flow passes through an 18-inch Parshall flume and is divided to flow in the relative amounts desired to each aeration channel. The primary effluent composite sample is taken as this point.

The influent to each channel is introduced at two points 225 feet from the north end of each channel (see Figure 3). The north-south channel length is approximately 1,050 feet. Return sludge combines with the influent flow to the east aeration channel at point E in Figure 3. In the west aeration channel, return sludge is pumped into the channel near point A (Figure 3). In addition, some of the solids settled out in the straightline settling unit (K in Figure 3) are re-suspended and directed into the aeration channel through common wall openings at the north end of unit K in Figure 3.

The mixed liquor from the east aeration channel discharges to an overflow weir trough (L) located in the channel and flows to a 58-foot diameter circular clarifier (J). The effluent from the circular unit flows to building M (Figure 3) where the flow rate is determined and a composite sample is taken. The flow then combines with the flow from the west aeration channel and flows to the Des Moines River. Chlorination disinfection can be conducted at this location. The settled solids are pumped to point E (Figure 3) where they are combined with the channel influent as return sludge. If sludge is to be wasted, it is pumped to a wet well at point A.

The mixed liquor from the west aeration channel was designed to flow through ports at the north curved end of the channel into the straightline settling unit (K). An effluent overflow weir trough is located at the south end (L) of the 475-foot long settling unit. The unit is 16 feet wide and 6 feet deep. The clarified effluent flows to building M where the flow is recorded and a composite sample is taken.

A 15-foot cage rotor was provided to prevent the accumulation of settled sludge solids beyond the 44-foot collector flight path which terminated north of the rotor in the straightline. The sludge hopper is at the north end of the unit. Sludge can be wasted from this hopper similar to the procedure for the waste sludge from the circular unit. Return sludge is as noted above.

The east aeration channel is equipped with 12 mini-magna rotors (Lakeside), 27.5 inches in diameter and 15 feet in length each. The rotors are normally operated at 93 revolutions per minute and can be immersed up to 10.5 inches as installed in this channel. Performance test data was not available for this modified rotor design at the time of the study.

The west aeration channel has 12 42-inch diameter magna rotors (Lakeside) with a total rotor length of 180 feet. These units are normally operated at 68 revolutions per minute and can be immersed up to 10.5 inches.

For normal conditions, the units are rated at 4.8 pounds of oxygen per hour per foot of rotor at zero dissolved oxygen in tapwater (at 20 degrees Celsius, C). The rotors also provide the velocity to maintain the solids in suspension.

In addition, each channel has one 50-horsepower and two 20-horsepower flotating aerators (Richards). The 20-horsepower units are each rated (by the manufacturer) at 1,400 pounds of oxygen per day and the 50-horsepower unit at 3,000 pounds of oxygen per day. Both ratings are at zero dissolved oxygen and in tapwater (at 20 degrees C). It should be noted that this application is not in accordance with normal installation practice for these aerators.

SECTION 5

OPERATIONAL EXPERIENCE - MECHANICAL

PLANT INTERRELATIONSHIPS

During the early months of operation, work continued in the processing area on connections to the wastewater treatment plant. Additional in-plant control measures were being developed and installed, i.e., a hydrasieve for hair removal. Several cases of discharges of excess or problem waste materials occurred. Examples include acid washing material, excess grease, blood, hair, toe nails, and tripe. Many of the cases were traced to problems with in-plant catch basins, valves, drains and various in-plant flow systems.

Typical treatment plant difficulties resulted, such as clogging of piping, pumping problems and damage to mechanical equipment. The hand-cleaned bar screen installation required additional operator time as a result of some of the discharges.

The importance of cooperation and correlation of operations was continually stressed and improvements have been noted. This is not a unique experience but again demonstrates the need for a close working relationship with product operations and wastewater treatment.

PRIMARY UNITS - AERATION, FLOTATION, SETTLING

The tubular conveyor units did not exert enough force or create an adequate velocity pattern to withdraw solids from a very large area near its bottom location. The settled solids that were not moved by the conveyor remained and tended to bridge near the conveyors. The organic solids became anaerobic and contributed to the poor performance of the primary units (see Figure D-6).

The chain drive mechanisms of the conveyors froze during winter operation. The drives were covered with metal shields and heating units were installed to prevent freezing (see Figure D-4).

The grease skimming flight operation was initially withdrawing large amounts of water with the grease. Staggered slots were cut in the flights to allow water to escape as the flight rose to the screw auger channel and this improved the quality of grease recovered.

One thousand-gallon cylindrical grease hauling tanks, with overflow shutoffs and steam heaters, were fabricated for continuous grease removal. The grease is returned to the processing plant for recovery.

AERATION CHANNELS

Cage type rotors (Lakeside) were initially installed in the east channel. It is understood that this was the first installation of a 15-foot length unit. Various difficulties developed during the first year of operation (November 1969 to November 1970). These included leaking seals, loose bolts, and bearing difficulties.

Cracking of the blades was also observed. The blades were tested and it was reported that they were cracking due to metal fatigue. Some of the lost blades damaged electrical conduits. Various new blade shapes and welding techniques were tried without success. The 12 cage rotors were replaced (by Lakeside) with 12 mini-magna rotors of a new design (November to December 1970). These units have continued in operation satisfactorily (see Figures D-8, D-11, and D-12).

The initial operation of the magna rotors also presented several problems. The problem of moisture entering the motors was corrected by installing motor covers to protect the units. Some rotors broke at the stub shaft weld. New welds were made and they have been satisfactory to date.

Considerable icing problems occurred during the two winters of operation. The catwalks were constructed adjacent to the rotors and the top of the rotor is near the catwalk surface. This resulted in considerable splashing onto the catwalks. Ice built up on and adjacent to the catwalks and rotors. Ice chunks that would break loose would damage the rotor blades and working conditions were hazardous in the areas near the rotors (see Figures D-13 and D-15).

Splash shields were designed and installed to control the icing problem. One shield design was curved to essentially cover the typical upward spray pattern of the rotor. These units have worked quite well. A flat vertical splash shield was also used. It is less effective but provided some relief (see Figures D-14 and D-16).

Another icing complication occurred during weekend operation with low flows. The long liquid retention time, extensive spraying and large air-water interface permited the lowering of the liquid temperature to freezing conditions. Condenser waters were directed to the treatment plant to help prevent or minimize icing conditions.

The floating aerators were added as a safety factor to provide additional aeration capacity. Some experimentation with wall mountings and cables was necessary to obtain a reasonably secure installation. The cone on each of the 50-horsepower units collapsed after about six months of operation. The units are normally utilized with greater depths and distances from walls and other

units. The cones were redesigned and replaced and they have continued in operation satisfactorily (see Figures D-9 and D-10).

STRAIGHTLINE SETTLING UNIT

This 475-foot long unit was located in the northern half of the western 16-foot wide interior channel. The unit is 6 feet deep and has a 44-foot long flight collector and a sludge hopper on the influent end. The design provided that the mixed liquor would enter through wall ports at the north end. During the settling phase, the flow was to the south end where the effluent discharged via an overflow weir trough. At the completion of the settling phase, a discharge valve would be closed. A cage rotor was turned on to re-suspend the solids that settled to the floor beyond the collector. The velocity pattern created in the channel would in essence permit the sedimentation unit to function as part of the west aeration channel via its interconnection at the wall ports in the north end of the unit.

The detention time and overflow rates are shown in Table 2.

TABLE 2. DETENTION TIME AND OVERFLOW RATE

Flow, mgd	Time, hrs.	Overflow rate, gpd/sq.ft.
1.0	8.3	130
1.5	5.5	196
2.0	4.1	260

It was originally intended that there would be a second settling unit in the southern half of the channel and the two units would operate alternately. Only the north unit has been utilized.

The cage rotor system did not re-suspend the solids adequately. To develop a flushing action, a door into the west aeration channel was installed at the sourh or clarified effluent end of the settler. This door was opened periodically (manually or on a time clock basis) and it was expected that the flow reversal along with the cage rotor would re-suspend the solids and return them to the aeration channel via the wall ports. This system did not function satisfactorily. Considerable turbulence developed in the region of the

effluent weir trough and solids were carried over the weir. This was due in part to the difficulty of sealing the flusing door. As in the above system, some of the settled solids were removed via the collector and hopper as desired. It was also difficult to obtain a concentrated sludge via the collector due to the turbulence near the wall ports in the sludge hopper area (see Figures D-17 through D-22).

Various modifications to the flushing operation were considered. The inlet to the straightline was relocated near the center of its length. This resulted in some performance improvement in effluent quality and solids concentration of the settled sludge solids.

The cycling operation of settling and re-suspension is also not desirable. A design modification employing a positive vacuum sludge withdrawal throughout the length of the unit was developed and proposed as a solution. The unit would be mounted on the side walls of the settler. It will also provide a controlled basis for sludge wasting and recycle which is not presently available for the west channel.

In summary, although the concept of utilizing an available interior channel has merit, the performance of the unit was not successful because of the design of the inlet, outlet and sludge collection system in the channel.

SECTION 6

PROCESS EVALUATION

PROJECT OBJECTIVES

The primary objective of this project was to determine the effectiveness of the channel aeration activated sludge process in achieving BOD and nitrogen removal from packinghouse wastewater. In meeting this objective, several component studies were included.

1. Evaluation of the performance of the in-plant and primary treatment units as they affect the performance of the activated sludge system.

2. Study of the effect of variations in process parameters such as retention time, mixed liquor solids levels and organic loadings on organic removal and waste sludge quantities.

3. Study of the nitrogen balance and process factors affecting it.

4. Evaluation of the performance of a new channel sedimentation unit design.

5. Evaluation of solids disposal systems including the potential of waste activated sludge as an animal feed supplement.

SAMPLING AND ANALYTICAL PROGRAM

Grab and composite sampling techniques were used in the study. Composite samples were collected from the plant influent, from the primary effluent and from each of the final clarifier effluents. Individual grab samples were taken at these locations and process points as needed.

The composite sample of plant influent was collected with a chain and scoop sampler. The sampler can be seen in Figure D-5 The primary effluent and final effluent samples were collected with a Lakeside Corporation Trebler Sampler. The composite samples were proportional to flow and the samples were refrigerated.

Normally, daily samples were collected at the composite locations. The number of tests conducted on the samples varied with the type of evaluation being conducted. The limited number of reported values in some of the tables resulted from neglecting data from periods of plant by-passing, composite sampler failures and other related equipment problems of which there were several instances as described in this report.

The following analyses were routinely conducted: chemical oxygen demand (COD), BOD_5, total suspended solids, volatile suspended solids, grease, ammonia nitrogen, chlorides, temperature. Total and filtrate COD and BOD_5 determinations were made to eliminate the effect of the final clarifiers in the process evaluation. The test procedures were conducted in accordance with US Environmental Protection Agency guidelines and the 12th Edition of Standard Methods for the Examination of Water and Wastewater, 1965 (United States Public Health Service). Additional tests were conducted on sludges and for control of the aeration channels (dissolved oxygen, MLSS, filamentous bacteria).

WASTEWATER CHARACTERISTICS

Table 3 presents the characteristics of the wastewater flow received at the treatment plant. The values are typical of packinghouse wastewater as noted in the Meat Industry Guide (United States Public Health Service. Industrial Waste Guide - Meat Industry. USPHS Publication Number 306. 1965), by Rohlich (Rohlich, G. A. Eutrophication and the Meat Industry. 65th Annual Meeting, American Meat Institute, University of Wisconsin, October 1970), and Steffen (Steffen, A. J. Waste Disposal in the Meat Industry - A Comprehensive Review. Proceedings of the Meat Industry Research Conference, March 1969). The flows received were approximately 15 percent lower than those predicted for design while the BOD load (36,000 pounds per day based on median values) closely approximated the predicted loading.

Figure 4 presents the LWK during the study period. The low period in April 1971 was during a period of partial plant shutdown. Other unusually low periods such as April and May 1972 relate to brief periods of kills limited to beef or pork only.

A selected data plot of total flow versus date is presented in Figure 5. Data from days on which any by-passing was practiced were eliminated to provide a proper representation of the actual flows. Most of the low flows represent weekend operation when production activities were very limited. There was a partial plant shutdown, as noted above, which reduced flows; most notably in the April 1971 period.

TABLE 3. CHARACTERISTICS OF WASTEWATER FLOW

Characteristic	90%	Median	10%	Pounds per 1,000 LWK	Number of Values
Live Weight Kill (LWK), lbs.	2,381	1,978	1,322	-	225
Flow rate, mgd	3.31	2.69	1.55	1,316*	223
Chemical Oxygen Demand (COD), mg/l	2,970	2,340	1,150	31.5	52
Biochemical Oxygen Demand (BOD_5), mg/l	2,670	1,600	900	16.5	101
Total suspended solids, mg/l	1,530	920	570	11.0	223
Volatile suspended solids, mg/l	1,060	725	480	9.6	62
Grease, mg/l	910	570	270	5.9	130
Ammonia nitrogen as N, mg/l	17.2	11.4	6.3	0.2	19
Chlorides, mg/l	2,000	1,310	985	20.9	17
COD/BOD ratio	2.94	1.86	1.05	-	28
Temperature, ^{o}F	-	89	-	-	-

*1,316 gallons per 1,000 LWK.

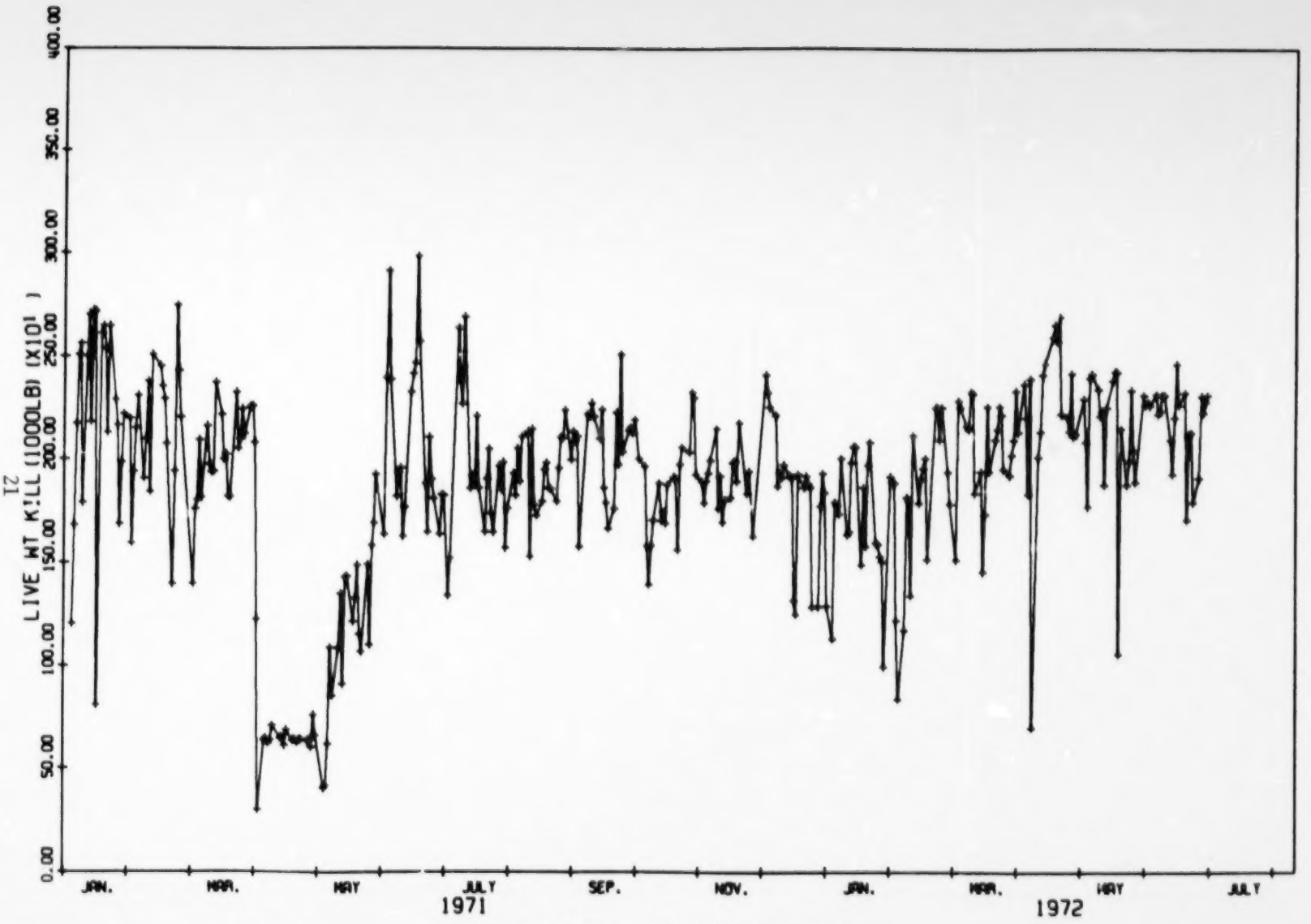

Figure 4. Live weight kill versus date.

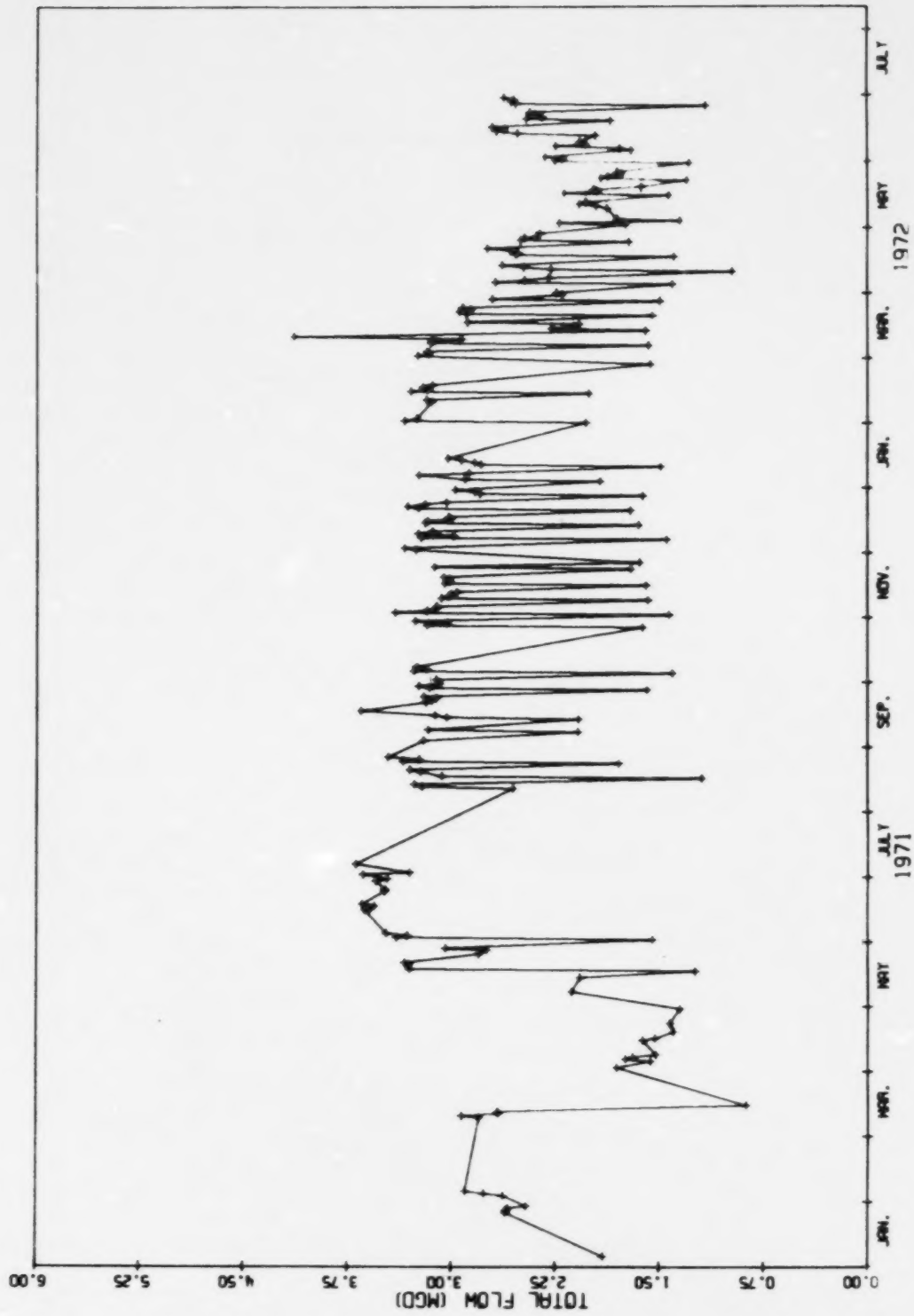

Figure 5. Total flow versus date

SECTION 7

PRIMARY TREATMENT PERFORMANCE

REMOVAL OF ORGANICS AND SOLIDS

Table 4 lists the performance of the primary units, Table 5 shows detention times and overflow rates for sedimentation unit, and Table 6 presents the primary effluent characteristics. The data presented and analyzed excludes periods of by-passing and includes analytical results based only on composite samples. The plant design was expected to obtain suspended solids and grease removals from 30 to 40 percent. These removals were not reached most of the time. The increase in ammonia nitrogen was due to a breakdown of the organic nitrogen (protein) which likely occurred in the sludge accumulation in the settling tank.

The aeration compartment has a nominal retention time of 15 minutes at 2.7 million gallons per day and 12 minutes at 3.3 million gallons per day. Air flow is restricted such that the minimum flow of air is supplied to provide flow velocities for facilitating grit removal. Operation with and without aeration showed no significant increase in grease removal in the gravity separation basin following the aeration compartment.

A limited study of grit removal quantities yielded values ranging from 390 to 800 pounds per day. This results in a median removal rate of 0.2 pounds of grit per 1,000 gallons of flow. Over 70 percent of the flow is subjected to grit removal in the packinghouse prior to discharge to the primary treatment unit. The tubular conveyors did not operate satisfactorily. During intermittent operation of the conveyors, solids tended to bridge over the inlet slot and hinder flow of sludge into the conveyor. Wear on the conveyor plates and chain is such that life expectancy is reduced to less than 2 years.

Plots of percent removal versus flow for suspended solids, grease and BOD are shown in Figures 6, 7, and 8. There is little or no correlation with flow rate. The settling unit overflow rates were high and the nominal retention time low. In addition, the peak flow to the treatment plant was normally sustained for approximately 12 hours each day with a peak to average flow rate ratio of 1.2 to 1 (see Figure 1).

In addition, the inadequate settled solids removal due to the performance of the tubular conveyors contributed to the poor performance. Anaerobic conditions developed in the unit which is evidenced by the release of ammonia nitrogen from the sludge. This increase in ammonia nitrogen resulted in an

TABLE 4. PERFORMANCE OF PRIMARY UNITS*

Parameter	90%	Median	10%	Number of Values
COD	32.2	12.2	- 4.5	47
BOD	29.9	9.5	- 7.4	82
Total suspended solids	43.8	18.6	- 9.6	194
Volatile suspended solids	35.7	11.1	- 26.9	58
Grease	49.8	22.8	- 5.6	115
Ammonia nitrogen as N	-23.4	-73.7	-279.0	18

*Percent removal.

TABLE 5. SETTLING UNIT DETENTION TIME AND OVERFLOW RATE

Flow, mgd	Detention Time, minutes	Overflow rate gpd/ft^2
2.0	70	1,000
2.7	52	1,350
3.5	40	1,750

TABLE 6. PRIMARY EFFLUENT CHARACTERISTICS

Characteristic	90%, mg/l	Median, mg/l	10%, mg/l	Number of Values
COD	2,660	2,040	1,080	48
BOD_5	2,315	1,400	725	87
Total suspended solids	1,190	724	450	195
Volatile suspended solids	915	636	436	59
Grease	660	420	220	119
Ammonia nitrogen as N	41.6	21.0	9.0	18
Chloride	1,930	1,330	1,060	17
COD/BOD ratio	2.81	1.86	1.24	26

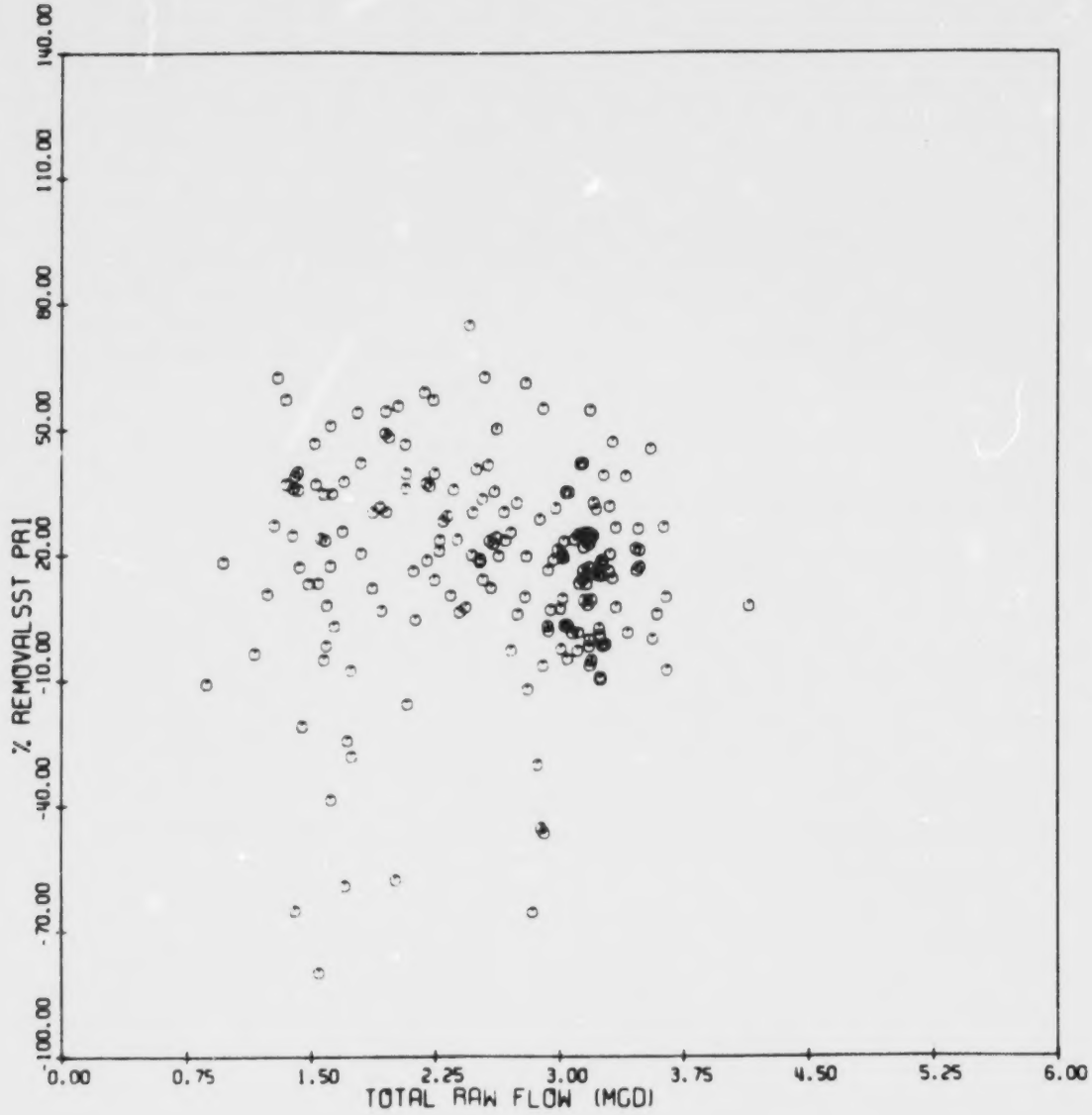

Figure 6. Percent removal suspended solids (primary) versus flow.

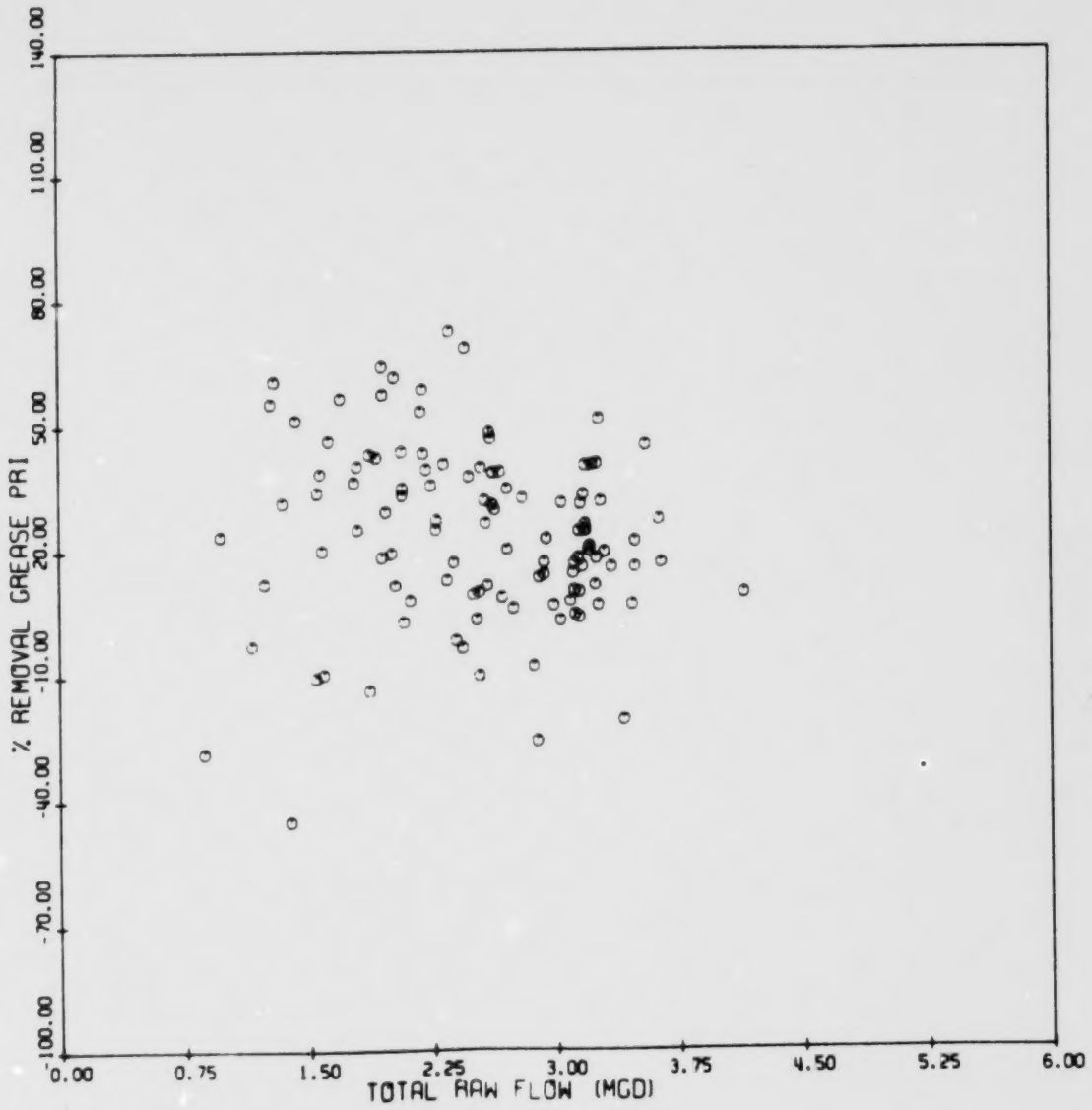

Figure 7. Percent removal grease (primary) versus flow.

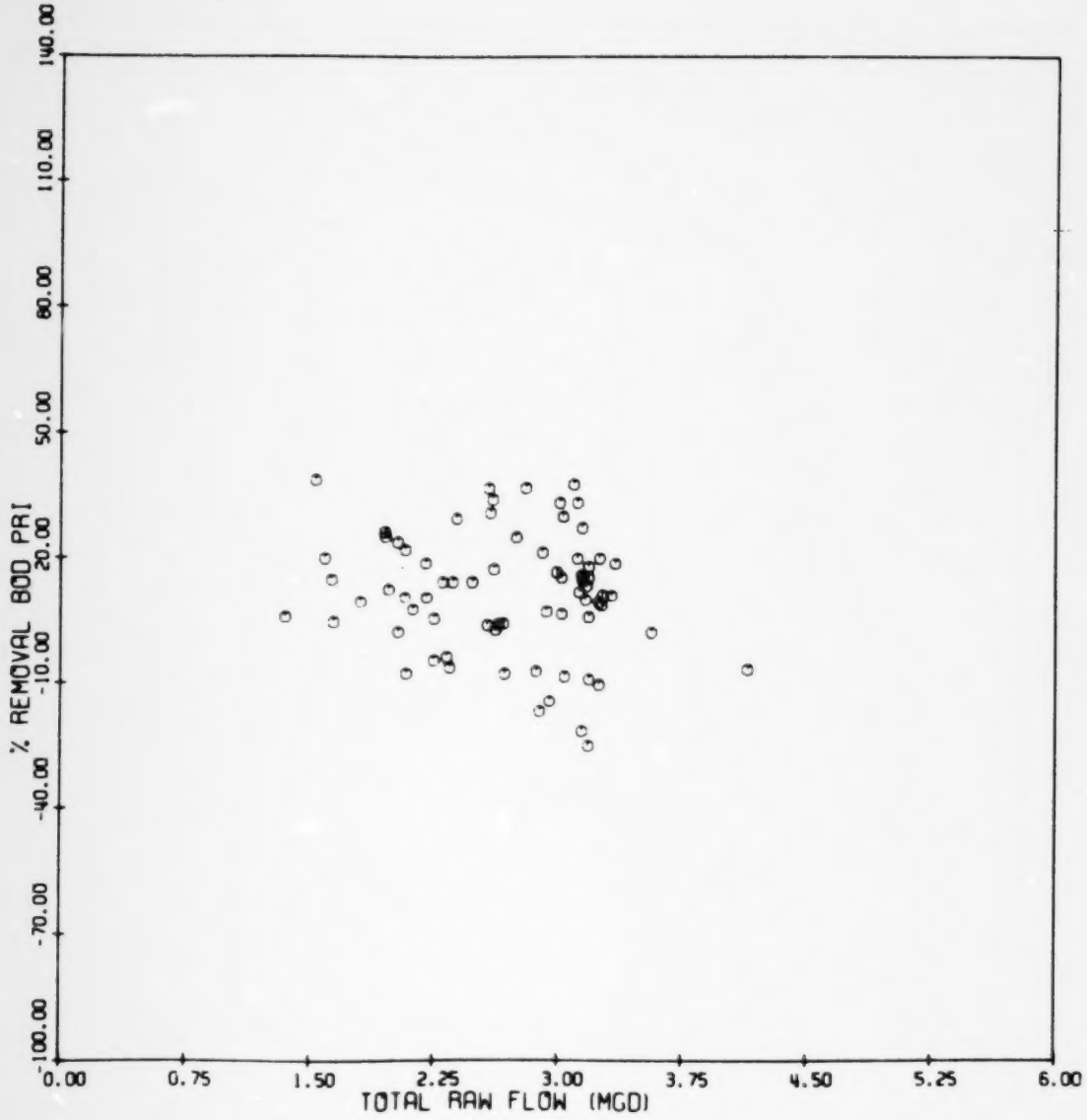

Figure 8. Percent removal BOD (primary) versus flow.

increased oxygen demand to the channel aeration system and it is also the primary cause of the increase in ammonia nitrogen in the treatment plant discharge.

The anaerobic activity also adversely affected the COD, BOD and suspended solids removals. Solids were buoyed to the surface and organics released from the settled solids. The resulting median primary effluent BOD loading to the secondary units was 34,500 pounds per day, which is 33 percent higher than design predictions of approximately 26,000 pounds per day.

SOLIDS AND GREASE DISPOSAL

Typical grit removal characteristics are are shown in Table 7 (December 1971):

TABLE 7. GRIT QUANTITIES AND CHARACTERISTICS

Total Solids, %	Total Volatile Solids, %	Weight, lb/day
18.5	13.8	385
38.4	19.0	800
22.6	18.1	470
33.8	20.4	700
20.8	16.6	435
26.8	18.6	535
27.4	-	560

The grit is high in organics ranging from 50 to 80 percent volatile. Landfill procedures were used for grit disposal.

Primary sludge removal was inadequate and the quantities were very low ranging from 600 to 2,000 gallons per day. The tubular conveyors cannot remove sufficient solids unless they are operated near continuously. However, the plant sludge hauling equipment had a limited capacity with a maximum

practical removal rate of approximately 6 gallons per minute (8,640 gallons per day). Sludge removal was normally conducted from 2 to 6 hours daily.

Typical primary sludge characteristics are shown in Table 8.

TABLE 8. PRIMARY SLUDGE CHARACTERISTICS

Parameter	Average, %	Range, %
Total solids	12.4	8-15
Total volatile solids	10.2	7-11
Grease content of dry solids	28.0	9-47
Protein content of dry solids	22.1	21-24

The volatile content averaged 82 percent and the sludge contained 50 percent grease plus protein. Recovery of the sludge solids under present operation is not feasible. The anerobic condition of the sludge solids and the relatively low protein content on a wet weight basis were the primary negative factors. Considering the quantity of suspended solids discharged with the primary effluent, primary treatment modifications could significantly increase the sludge collected and increase the potential for its use in a by-product.

Grease skimmings from the primary unit averaged approximately 2,700 pounds daily. The skimmings are returned to the rendering department for grease salvage. The grease content averaged 12.5 percent on a wet weight basis.

PILOT PLANT STUDY - DISSOLVED AIR FLOTATION

In order to evaluate potential means for recovering grease and protein plus improving the waste treatment plant performance, a dissolved air flotation pilot plant study was conducted. A 30 gallon per minute unit was operated for a 2-week period. Raw waste after bar screening was supplied as a feed source. The waste had a COD of 3,570 milligrams per liter, a suspended solids concentration of 1,390 milligrams per liter and a grease content of 970 milligrams per liter.

The performance of the flotation unit is shown in Table 9. The values in parentheses are the values for the existing primary treatment units (see Table 4).

TABLE 9. PERFORMANCE OF DAF UNIT*

	Grease	COD	Suspended Solids
Average	77.6 (22.8)	61.4 (12.2)	64.0 (18.6)
Range	63-93	43-80	50-83

*Percent removal.

It can be seen that the dissolved air flotation performance is substantially better than the existing plant units. Using a flow rate of 2.80 million gallons per day and median values for primary effluent from Table 6, the dissolved air flotation unit would reduce aeration tank loadings for COD 33 to 56 percent, for suspended solids 31 to 54 percent and for grease 48 to 70 percent. These improvements are based on the pilot unit, its effluent quality during the study and a predicted effluent quality using median raw wastewater characteristics from Table 3. A full scale unit would probably not be as efficient. However, the changes would still be very significant.

The value of the recoverable solids was also evaluated. The solids were analyzed as 52 percent grease and 17 percent protein. Based on 75 percent grease removal with a flotation unit, the value of the recovered solids was estimated at from $128,000 to $186,000 per year based on a solids value of from 4.5 to 6.5 cents per pound recovered.

One equipment manufacturer indicated that the existing primary treatment units could be modified to function as a dissolved air process. The estimated cost for the equipment and installation was approximately $60,000. This modification would probably yield approximately 60 percent grease removal. An approximate estimate of $250,000 was received for a complete separately installed dissolved air flotation system. This system would achieve at least 75 percent grease removal.

SECTION 8

SECONDARY TREATMENT PERFORMANCE

The total secondary treatment system consisted of two parallel flow systems receiving an identical influent as shown in Figure 2. They are the east aeration channel followed by a circular clarifier and the west aeration channel followed by a straightline settling unit. Each system operated independently and their respective performance will be considered separately.

EAST CHANNEL (I) - CIRCULAR SETTLER

The operational characteristics of the east channel are presented in Table 10. The flow to the channel is presented in Figure 9. The flow to the channel was reduced to meet channel optimum operation and aeration capacity. The east channel received approximately 35 percent of the plant loading. The dissolved oxygen concentration is plotted in Figure 10. Most of the high values are weekend or Monday values. The channel dissolved oxygen rose with the light loading on weekends and normally was higher on Monday as a result.

The variation in channel temperature with time is ploted in Figure 11. The temperature followed ambient air temperature changes as would be expected. Several values near 40 degrees Farenheit (F) were recorded even with a median influent temperature of 89 degrees F.

The MLSS level was also limited by aeration capacity. The MLSS levels are plotted in Figure 12. Oxygen deficiencies and odor problems were observed at the higher levels of MLSS.

The resulting organic loadings were similar to a lightly loaded conventional process although the hydraulic retention time was quite long with a median value of 3.6 days. Waste sludge data was limited; however, an approximate solids retention time (SRT) was from 5 to 6 days. This was based on a waste sludge rate of 4,000 to 6,000 pounds per day plus the loss of solids in the final effluent. The SRT was lower than anticipated due to the low MLSS levels and limited aeration capacity.

The final effluent characteristics are presented in Table 11 and the removal performance in Table 12. The removal percentages are based on primary effluent values.

The total effluent BOD_5 meets the State requirement for this plant 50 percent of the time. The poor performance periods of the east side were

TABLE 10. OPERATIONAL CHARACTERISTICS - EAST AERATION CHANNEL (I)

Characteristics	90%	Median	10%	Number of Values
Flow, mgd	1.47	0.98	0.54	214
Detention time, days	6.4	3.6	2.4	214
Mixed liquor, suspended solids, mg/l	2,010	1,425	950*	361
Mixed liquor, volatile suspended solids, mg/l	1,650	1,250	1,025*	86
Sludge Volume Index	735	382	85	359
Dissolved oxygen, mg/l	4.2	0.8	0.1	353
Temperature, ^{o}F	80	63	45	340
Applied BOD_5, lb/day	20,000	11,900	6,500	77
Volumetric loading, lbs/1,000 cu.ft.	41.9	24.7	13.7	77
Loading factor, lbs/lb MLSS	0.40	0.26	0.15	77

*The larger 10 percent value for mixed liquor volatile suspended solids is an abnormality due to the data available and statistical analysis conducted.

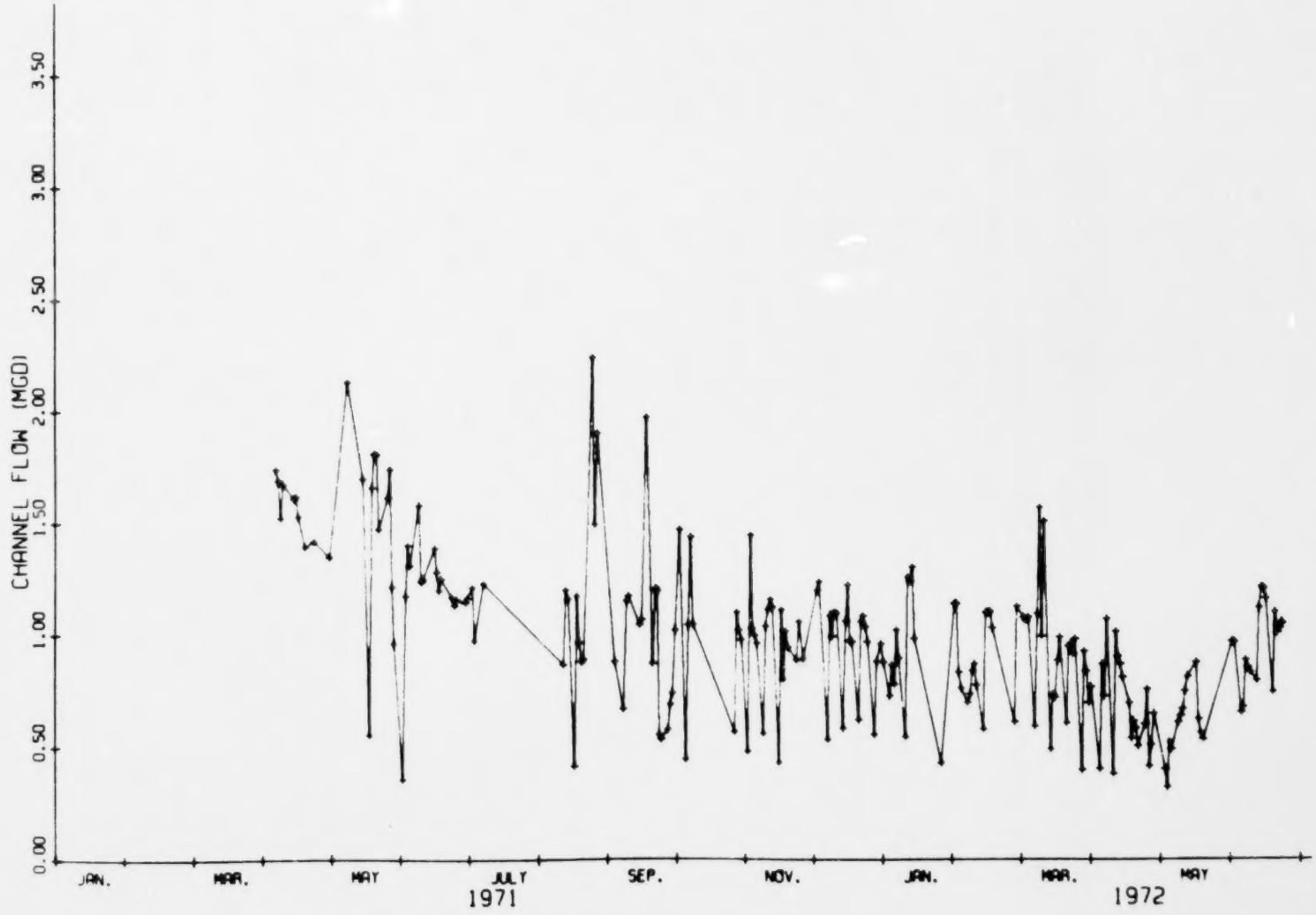

Figure 9. East channel flow versus date.

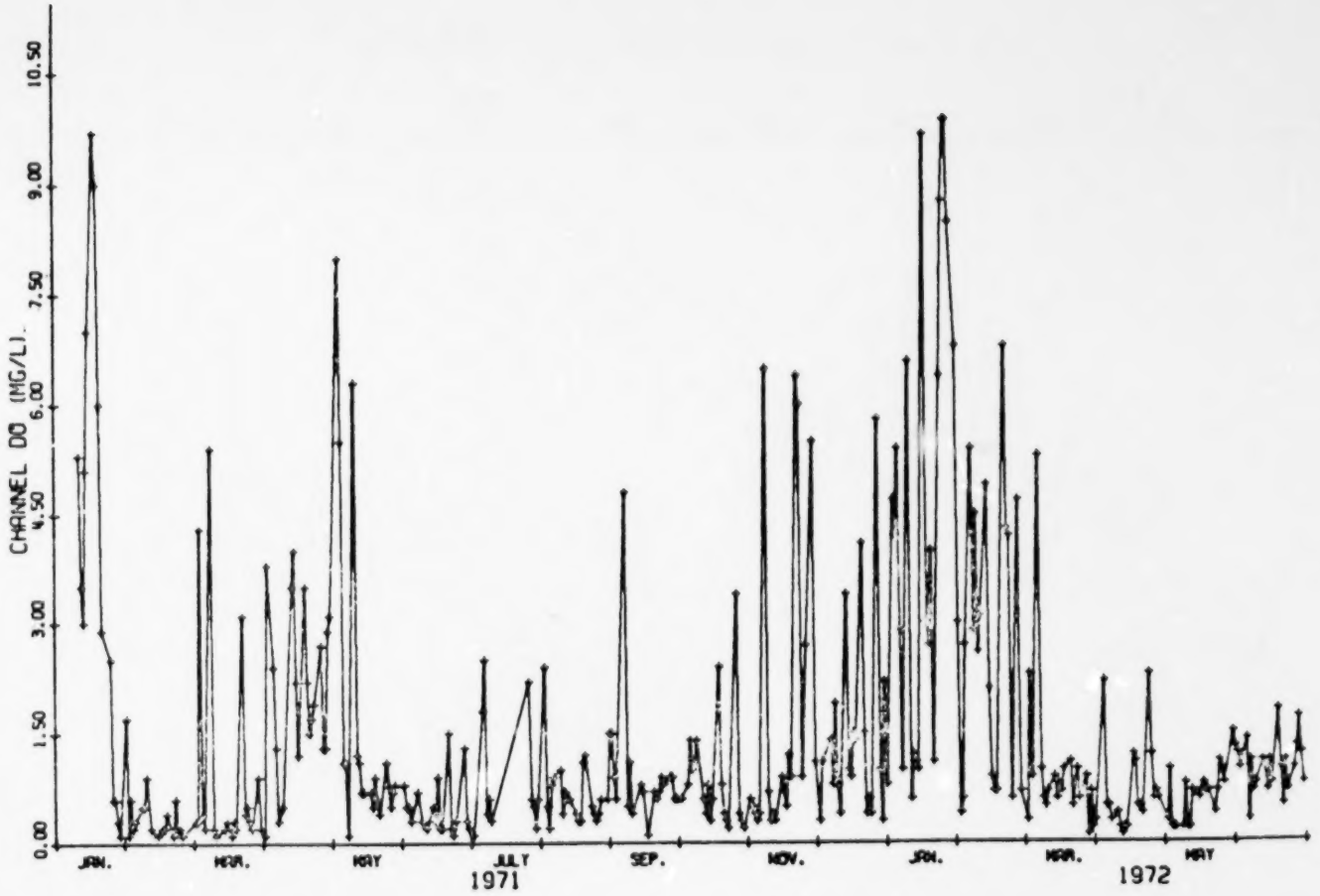

Figure 10. East channel dessolved oxygen versus date.

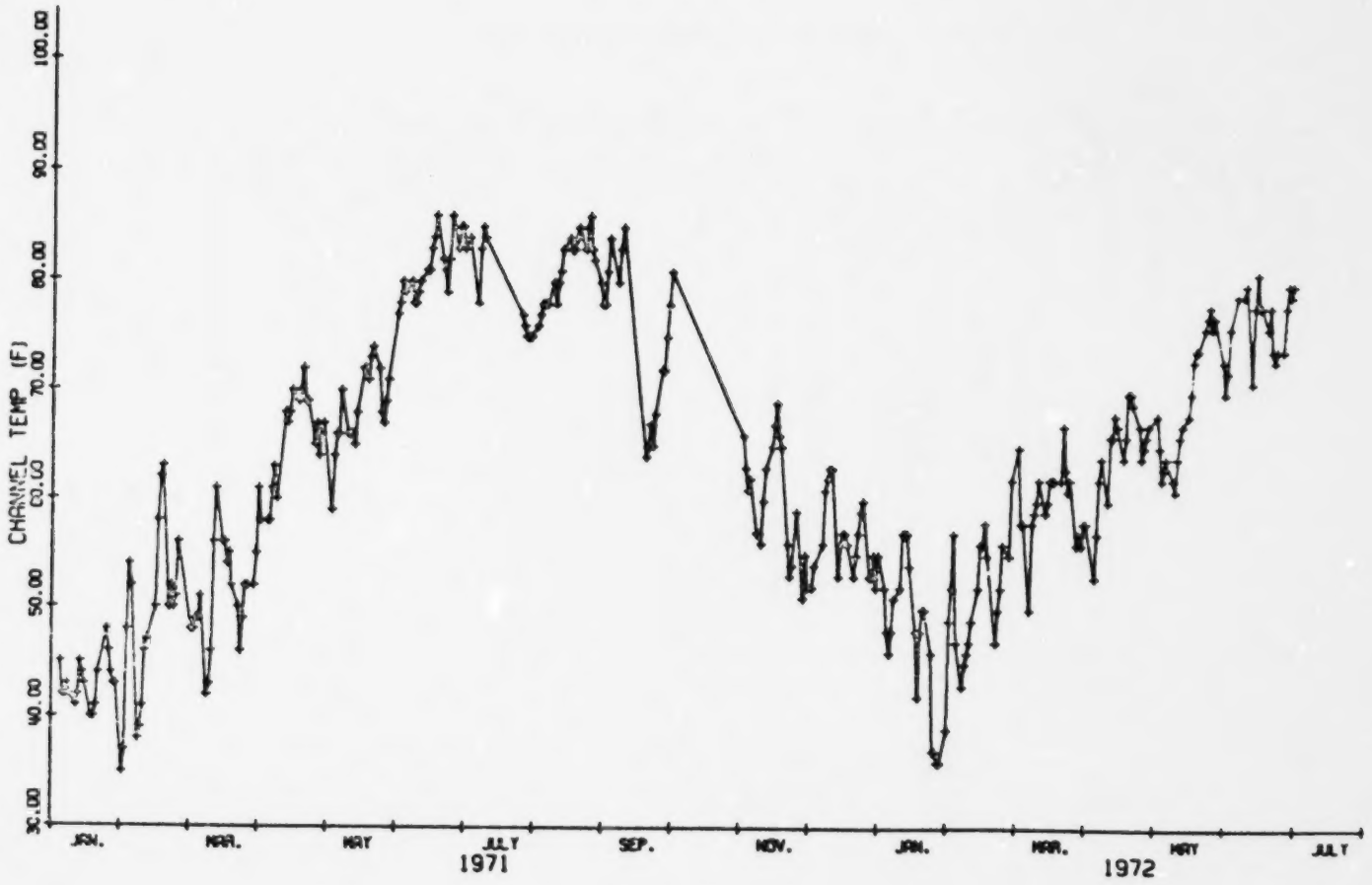

Figure 11. East channel temperature versus date.

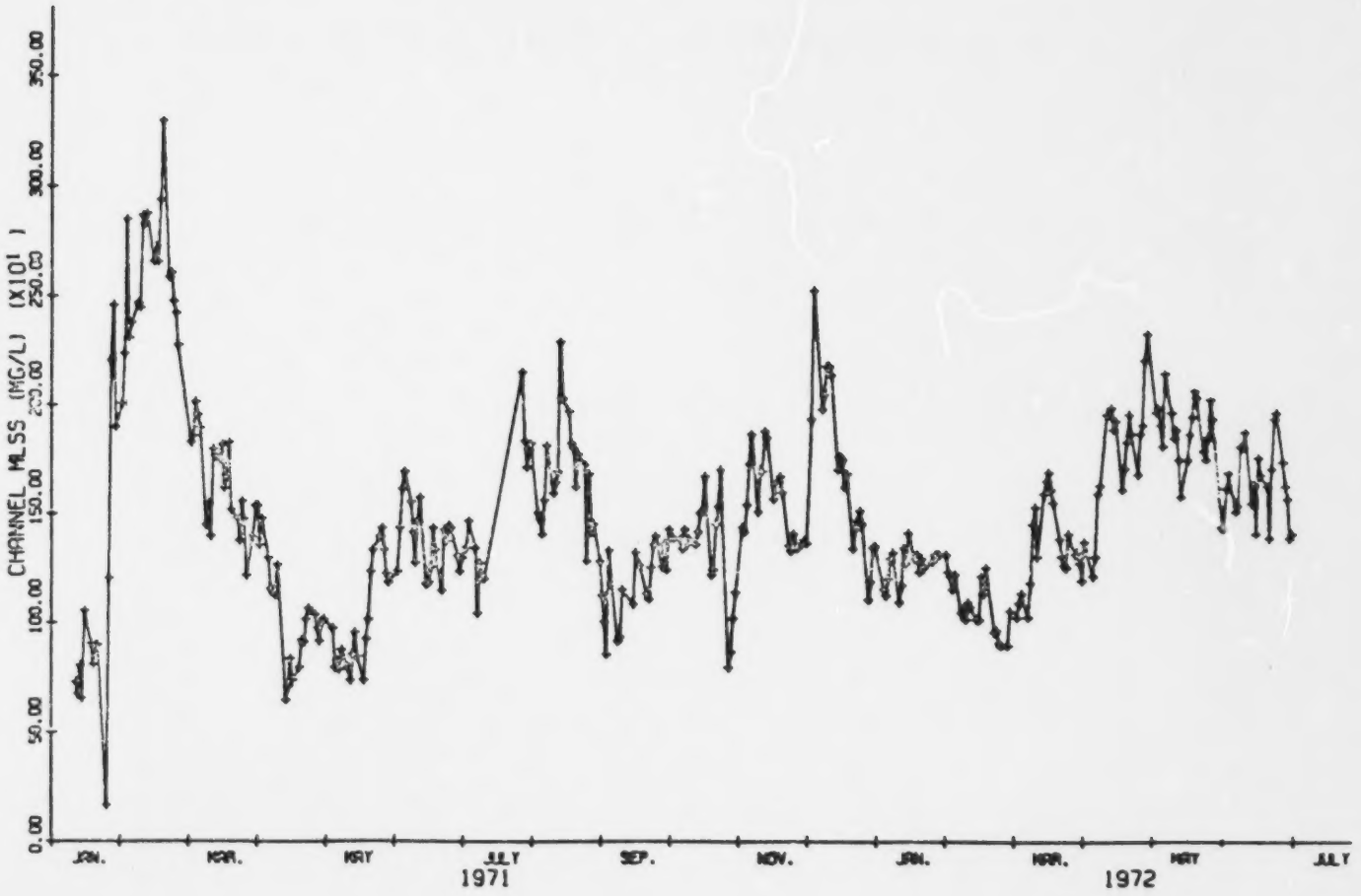

Figure 12. East channel MLSS versus date.

TABLE 11. FINAL EFFLUENT CHARACTERISTICS - EAST AERATION CHANNEL (I)

Item	90%, mg/l	Median mg/l	10%, mg/l	Number of Values
Total COD	695	260	86	61
Filtrate COD	260	102	58	29
Total BOD	455	70	21	125
Filtrate BOD	92	22	6	26
Total suspended solids	840	142	31	233
Volatile suspended solids	372	42	16	55
Grease	77	21	5	37
Ammonia nitrogen as N	32.0	18.3	6.4	29
Pounds of Effluent Parameter per 1,000 Pounds Live Weight*				
Total COD	8.8	3.7	1.0	59
Filtrate COD	3.2	1.3	0.78	29
Total BOD	5.6	0.9	0.26	125
Filtrate BOD	1.0	0.21	0.09	26
Total suspended solids	11.3	1.6	0.33	230
Grease	1.0	0.22	0.06	35
Ammonia Nitrogen as N	0.45	0.25	0.09	29

*Based on flow distribution to the respective channels.

TABLE 12. PERFORMANCE OF SECONDARY UNITS - EAST CHANNEL (I)

Item	90%	Median	10%	Number of Values
Total COD removal	95.9	87.3	45.8	52
Filtrate COD removal (total-filtrate)	97.3	95.5	84.1	26
Total BOD removal	97.9	94.8	65.6	80
Filtrate BOD removal (total-filtrate)	99.2	98.1	87.5	22
Total suspended solids removal	-	80.4	-	-
Grease removal	98.5	93.9	78.7	30
Ammonia nitrogen removal	83.2	1.1	-71.7	15

largely related to the poor settling characteristics of the sludge and limiting aeration capacity for the system. The variation in the sludge volume index during the study period is presented in Figure 13. Figure 14 presents a plot of the sludge volume index versus the effluent total suspended solids from the clarifier. High sludge volume indices generally correlated with high effluent suspended solids and BOD values. During some periods of high sludge volume index values, the sludge was examined microscopically and significant numbers of filamentous bacteria were present. The mixed liquor also contained from 11 to 14 percent grease and pieces of hair were observed.

The effluent suspended solids are plotted against flow in Figure 15. The effluent suspended solids variations did not correlate with flow rate. The detention time and overflow rate of the circular clarifier are shown in Table 13.

TABLE 13. CIRCULAR CLARIFIER DETENTION TIME AND OVERFLOW RATE

Flow, mgd	Detention Time, hrs.	Overflow Rate, gpd/sq.ft.
0.5	8.6	190
1.0	4.3	380
1.5	2.8	570
2.0	2.1	760

The overflow rates are within acceptable design limits (see Figure D-23).

The BOD removal was analyzed with respect to the volumetric loading and loading factor values and no correlation was evident. The volumetric loading and loading factor are plotted against percent removal of BOD in Figures 16 and 17, respectively.

Changes in the ammonia concentration varied considerably. The median final effluent value of 18.3 milligrams per liter is high and would be of concern in plant discharges to small streams. Factors affecting the nitrogen balance include the high proteinaceous organic loading, the limited aeration capacity and the relatively low solids retention time. Temperature may also be a factor during winter operation.

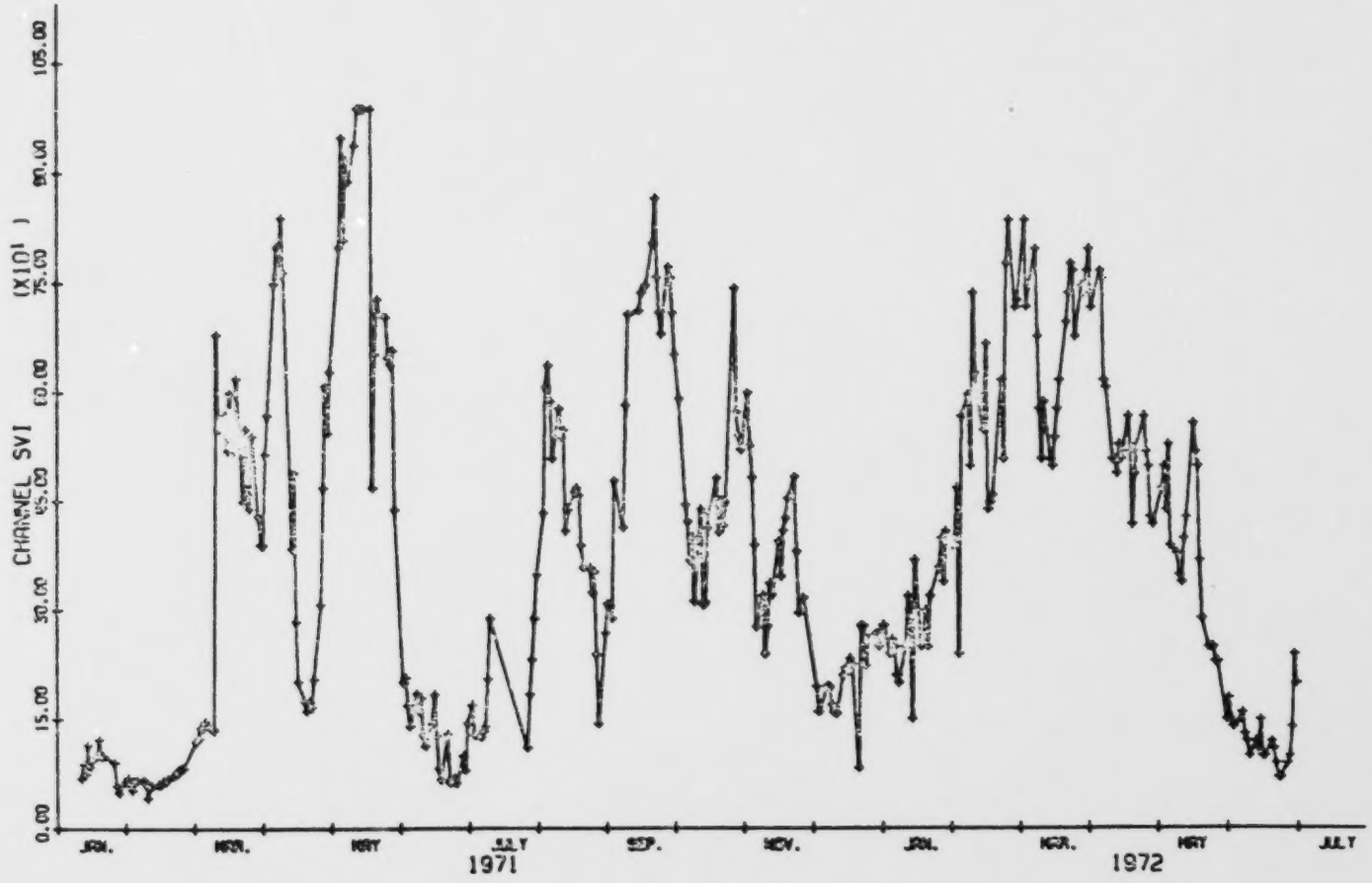

Figure 13. Sludge volume index versus date (east).

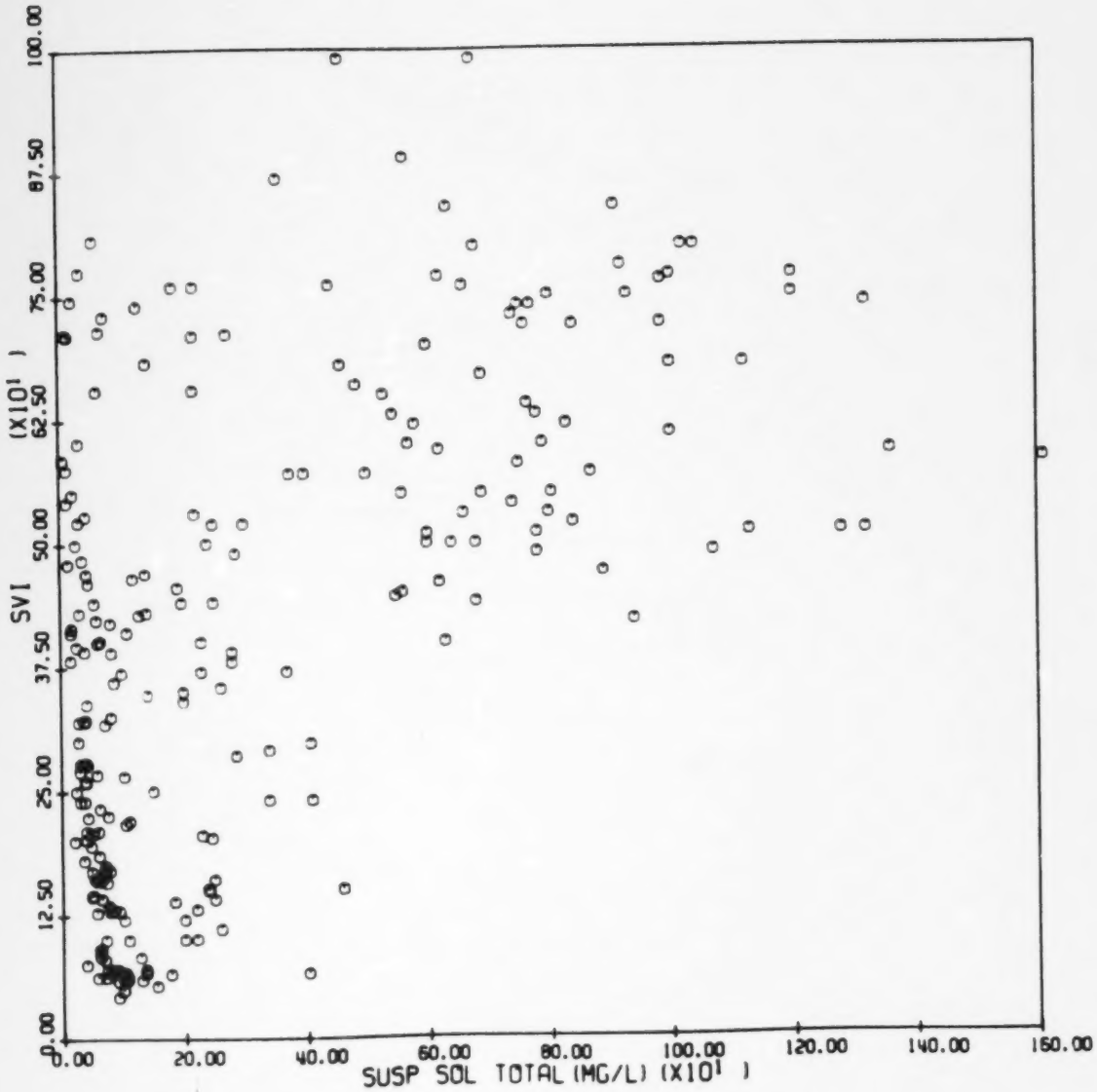

Figure 14. Sludge volume index versus effluent suspended solids (east).

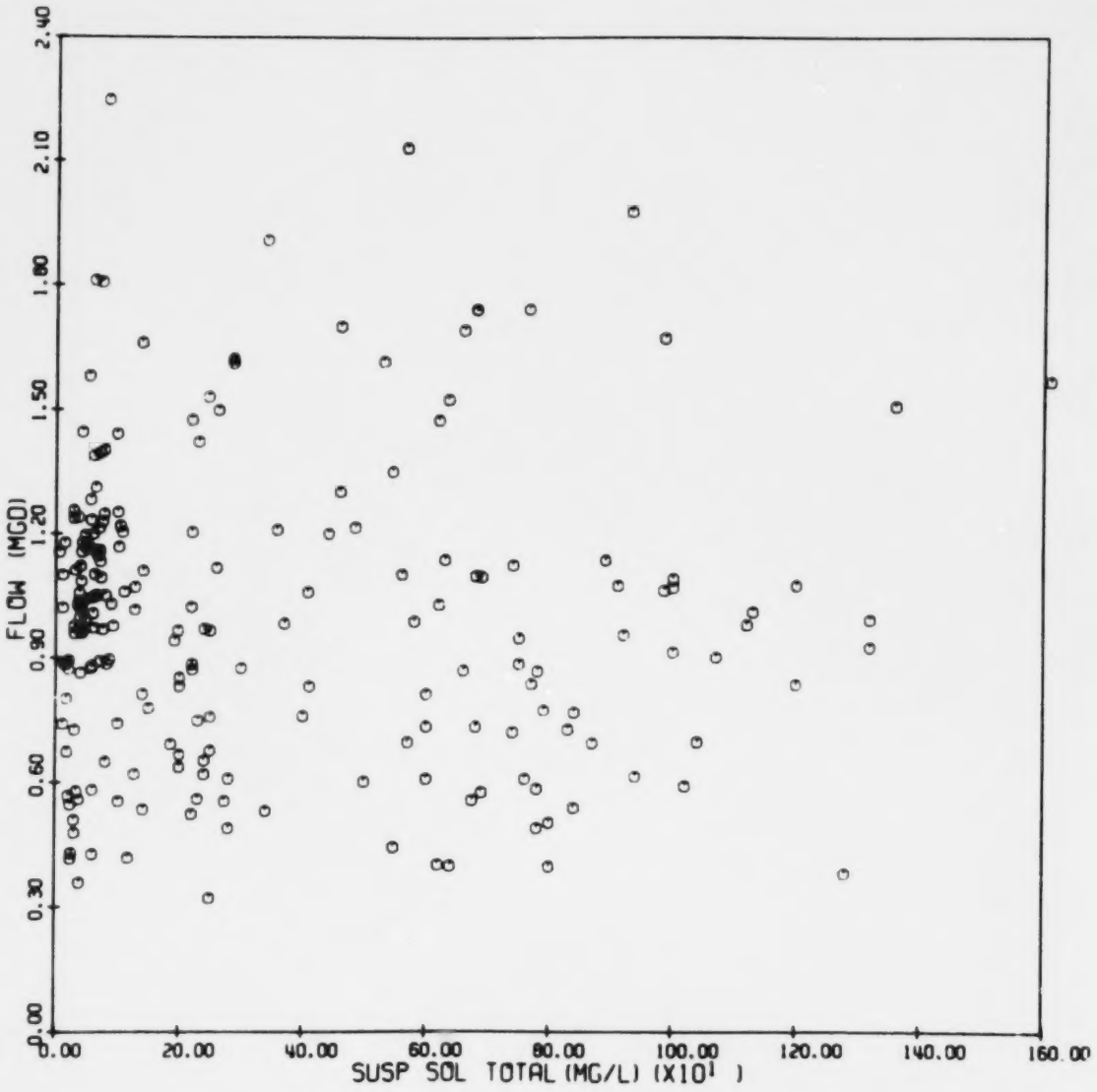

Figure 15. Flow rate versus effluent suspended solids (east).

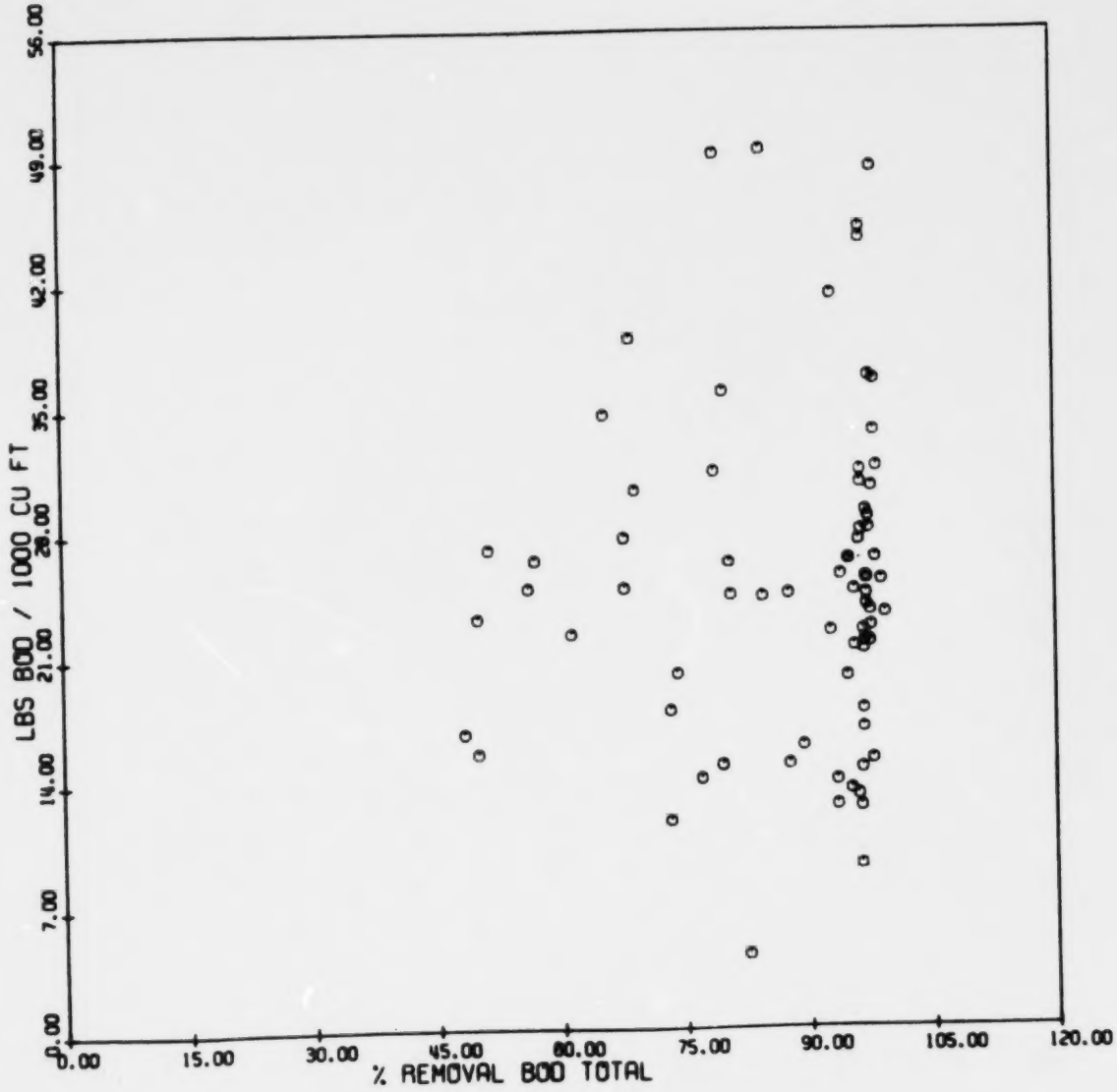

Figure 16. Volumetric loading versus percent removal BOD (east).

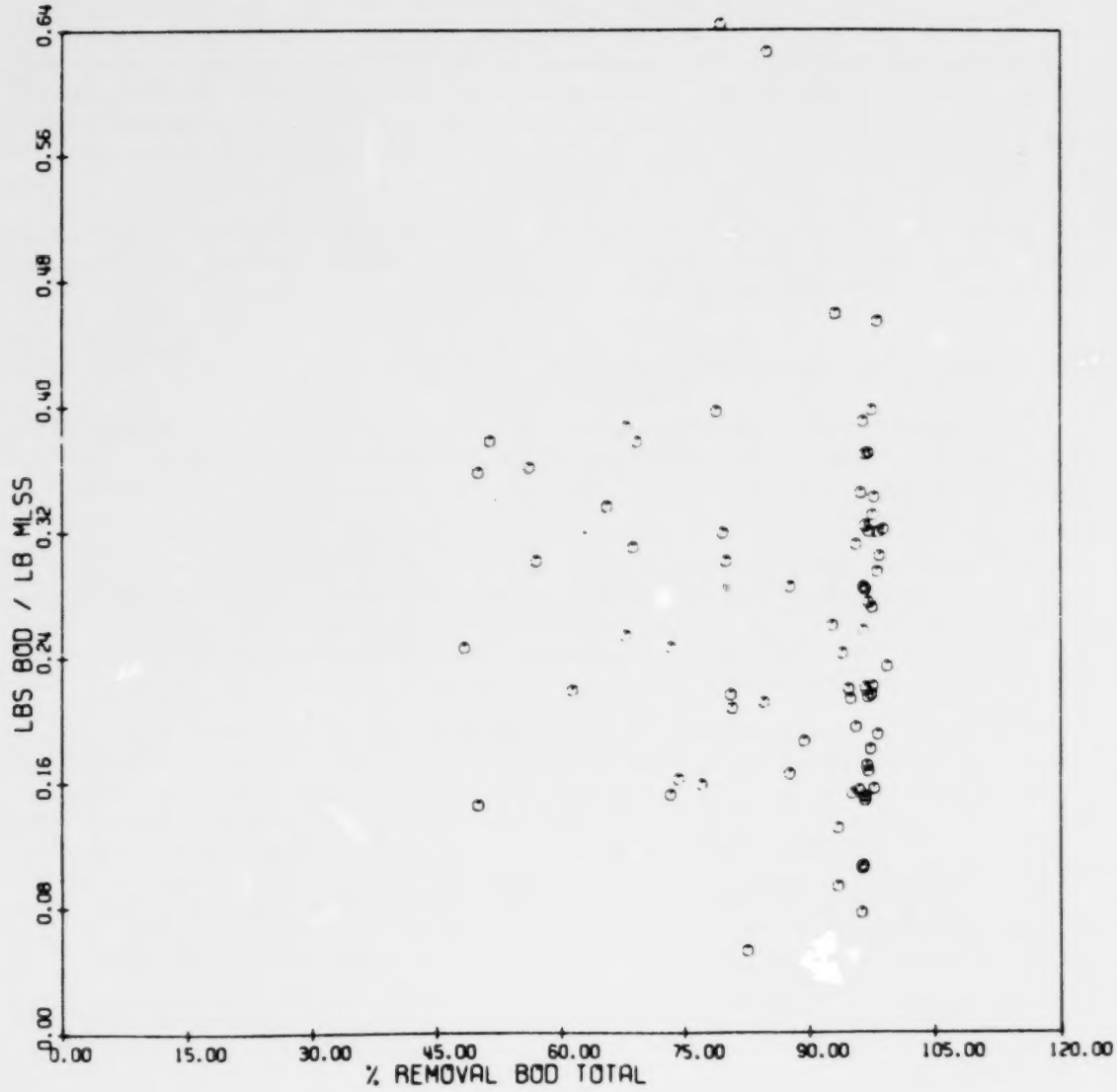

Figure 17. Loading factor versus percent removal BOD (east).

The east rotor aeration system was a new design and no performance data was available. The application of the floating aerators also was not under normal design conditions. In addition, the 50-horsepower unit was redesigned during the early phase of the project.

An approximation of the oxygen transfer capacity of the east aeration channel (12 mini-magna's and 3 floating aerators) can be obtained by considering the pounds of BOD_5 satisfied in the aeration system. Using the median channel loading of 11,900 pounds per day and a 98.1 percent removal (Total-Filtrate in Table 12), the channel aeration system met an oxygen demand (BOD_5) of 11,670 pounds per day. During most of the period, 10 rotors were in operation.

Based on median values, the overall treatment plant removals (untreated versus total east effluent) would be 95.7 percent BOD_5, 84.6 percent suspended solids and 96.3 percent for grease.

WEST CHANNEL (II) - STRAIGHTLINE SETTLER

The operational characteristics of the west channel are presented in Table 14. The channel flow rate is plotted versus date in Figure 18. The low values are normally weekend flows. Days of by-passing have been excluded. The west channel received 65 percent of the plant loading or 1.85 times the loading of the east channel. This loading distribution was a result of the greater aeration capacity in the west channel. The dissolved oxygen and MLSS levels are presented in Figures 19 and 20, respectively. The dissolved oxygen levels are relatively low (median 0.8 milligrams per liter) as are the MLSS levels. This resulted from the higher than predicted organic loadings and limited aeration capacity.

The median organic loading (0.56 pounds BOD_5 per pound MLSS) was higher than the conventional activated sludge process and the median hydraulic retention time of 1.9 days exceeded that for many extended aeration systems. Due to the nature of the final settling tank operation, reliable waste sludge information was not available. However, there was a significant loss of solids in the final effluent. Based on median values, approximately 10,000 pounds of solids were discharged daily. Therefore, the solids retention time in the west channel was in the range of 3 to 4 days. During several operational periods, solids were also intentionally wasted from the unit.

The final effluent characteristics are presented in Table 15 and the removal performance in Table 16. The removal percentages are based on primary effluent values.

The effluent quality from the west system was consistently poor. This poor performance is related to the operation of the straightline settling unit and to periods of poor sludge settling properties. The sludge volume index values are plotted against date and effluent suspended solids in Figures 21 and 22. Filamentous bacteria were identified in some sludge samples.

TABLE 14. OPERATIONAL CHARACTERISTICS - WEST AERATION CHANNEL (II)

Item	90%	Median	10%	Number of values
Flow, mgd	2.23	1.83	0.96	183
Detention time, days	3.6	1.9	1.6	183
Mixed liquor suspended solids, mg/l	1,960	1,320	925	342
Mixed liquor volatile suspended solids, mg/l	1,540	1,050	690	85
Sludge volume index	670	320	132	343
Dissolved oxygen, mg/l	5.6	0.8	0.2	332
Applied BOD_5, lb/day	41,200	22,600	13,200	72
Volumetric loading, lbs/1,000 cu.ft.	86.5	47.4	27.6	72
Loading factor, lbs/lb MLSS	0.91	0.56	0.28	72

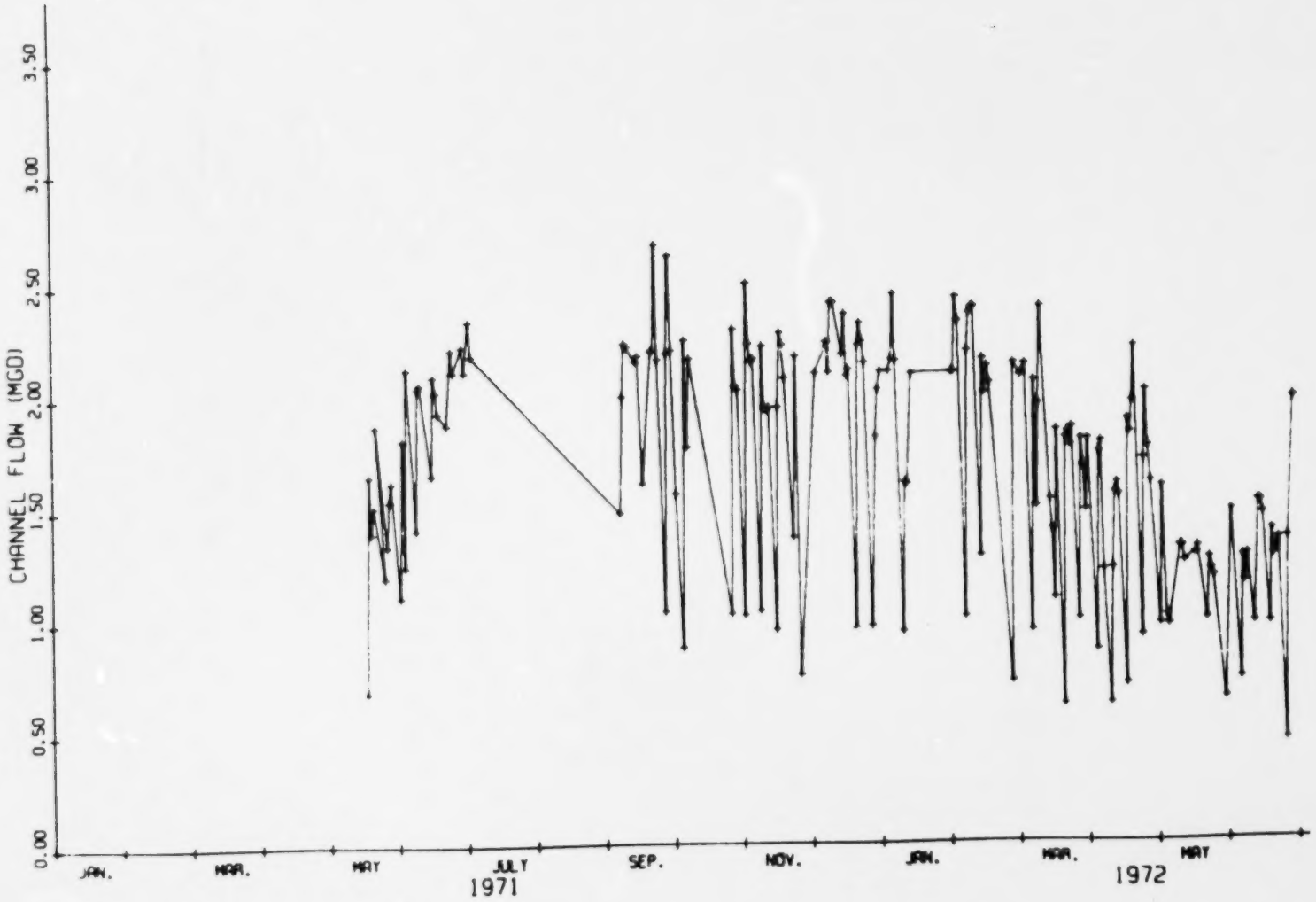

Figure 18. West channel flow versus date.

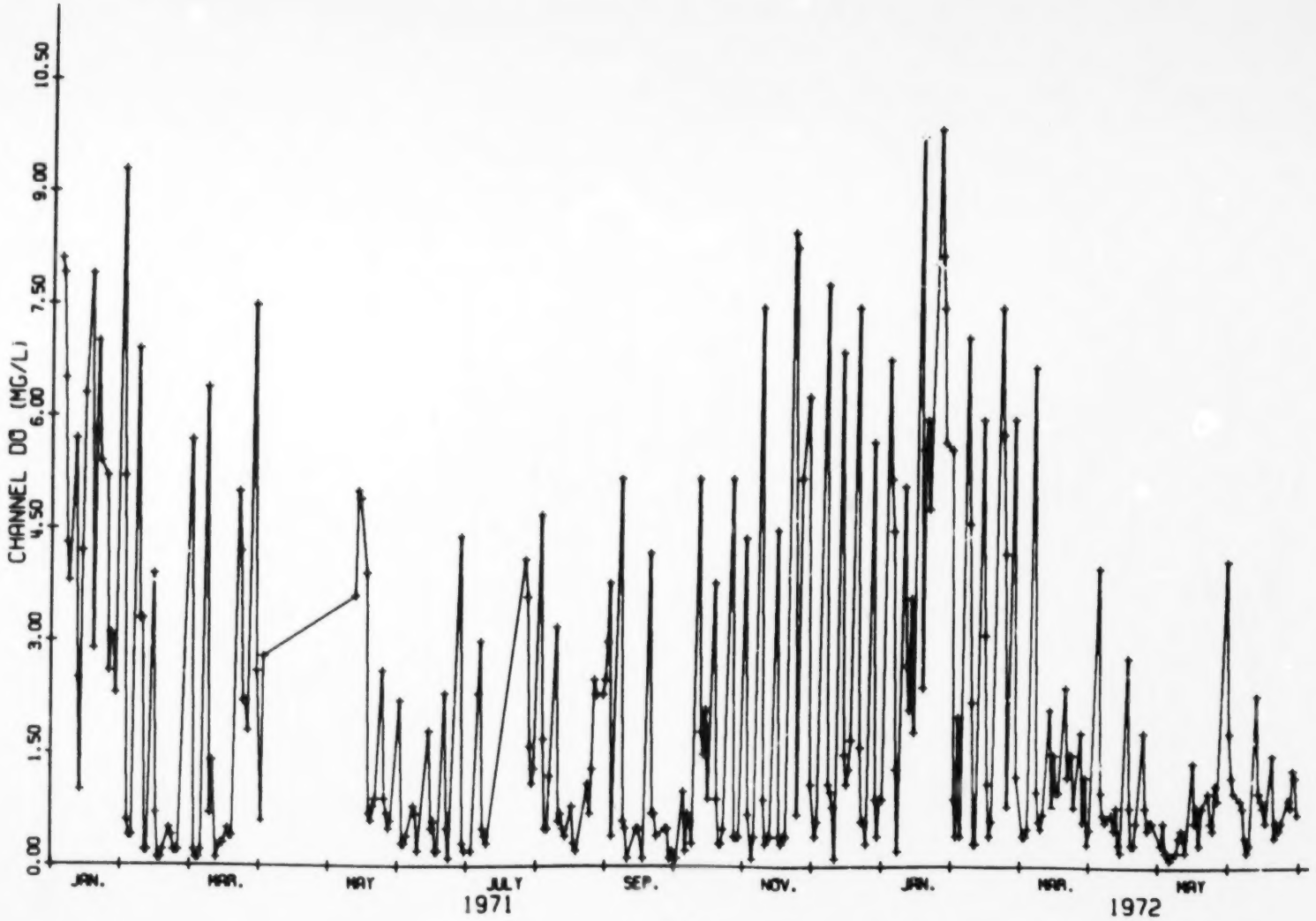

Figure 19. West channel dissolved oxygen versus date.

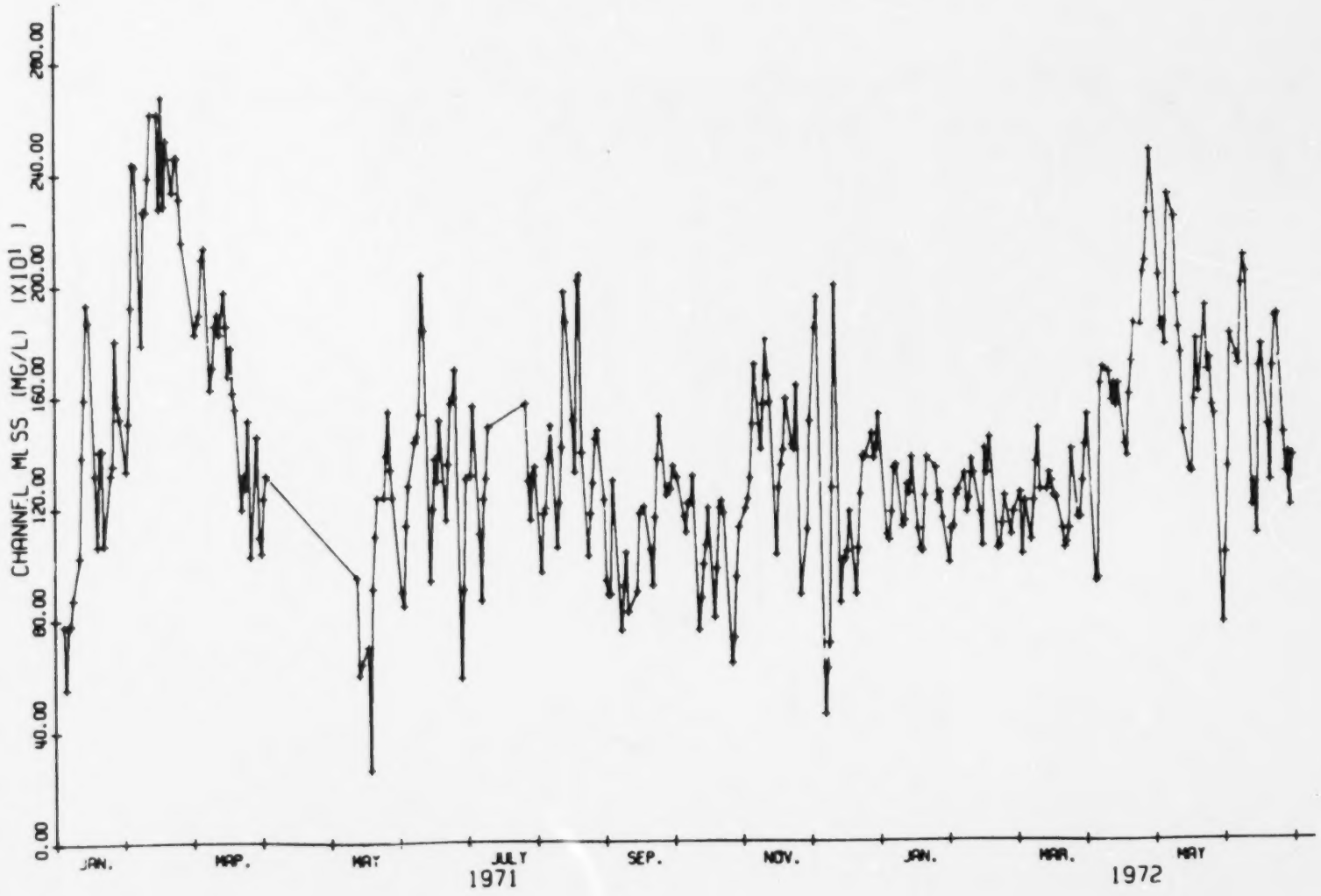

Figure 20. West channel MLSS versus date.

TABLE 15. FINAL EFFLUENT CHARACTERISTICS - WEST AERATION CHANNEL (II)

Component	90%, mg/l	Median, mg/l	10%, mg/l	Number of values
Total COD	1,535	880	210	31
Filtrate COD	200	95	54	16
Total BOD	780	530	92	83
Filtrate BOD	48	19	5	16
Total suspended solids	1,250	670	115	188
Volatile suspended solids	820	270	66	54
Grease	295	120	19	26
Ammonia nitrogen as N	38.5	24.6	6.4	26
Pounds of Effluent - Parameter per 1,000 Pounds Live Weight*				
Total COD	21.7	9.2	3.3	29
Filtrate COD	3.2	1.2	0.60	16
Total BOD	9.5	5.3	1.1	83
Filtrate BOD	0.7	0.25	0.07	16
Total suspended solids	13.7	6.8	1.6	185
Grease	3.6	1.7	0.29	25
Ammonia nitrogen as N	0.56	0.30	0.10	26

*Based on flow distribution to the respective channels.

TABLE 16. PERFORMANCE OF SECONDARY UNITS - WEST CHANNEL (II)*

Item	90%	Median	10%	Number of values
Total COD removal	88.2	53.2	-13.3	30
Filtrate COD removal (total-filtrate)	97.4	95.4	87.9	16
Total BOD removal	92.2	67.1	38.7	65
Filtrate BOD removal (total-filtrate)	99.3	98.1	94.2	16
Total suspended solids removal	-	7.5	-	-
Grease removal	92.9	66.0	- 7.2	24
Ammonia nitrogen removal	70.0	-50.5	-164	14

*Percent removal.

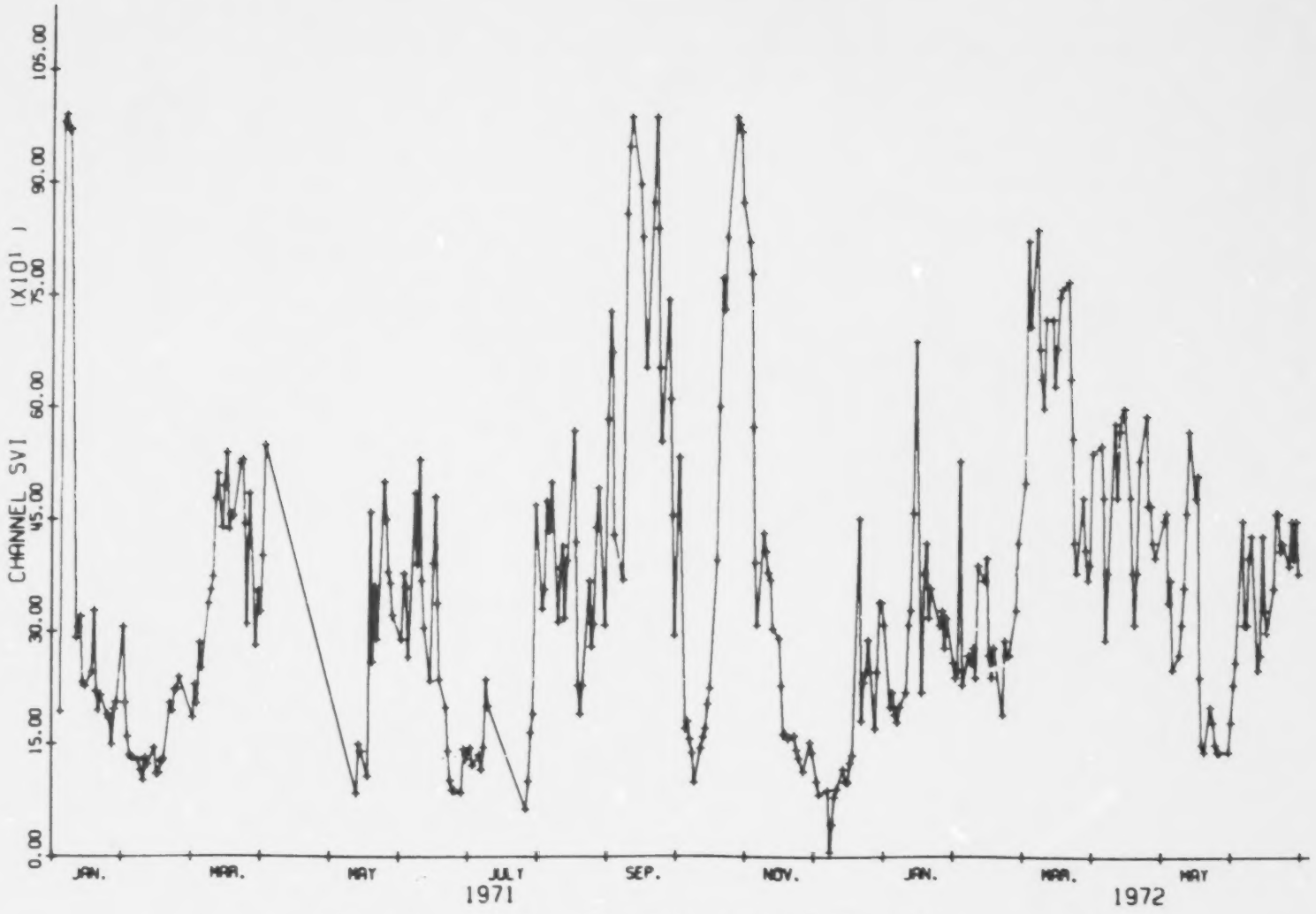

Figure 21. Sludge volume index versus date (west).

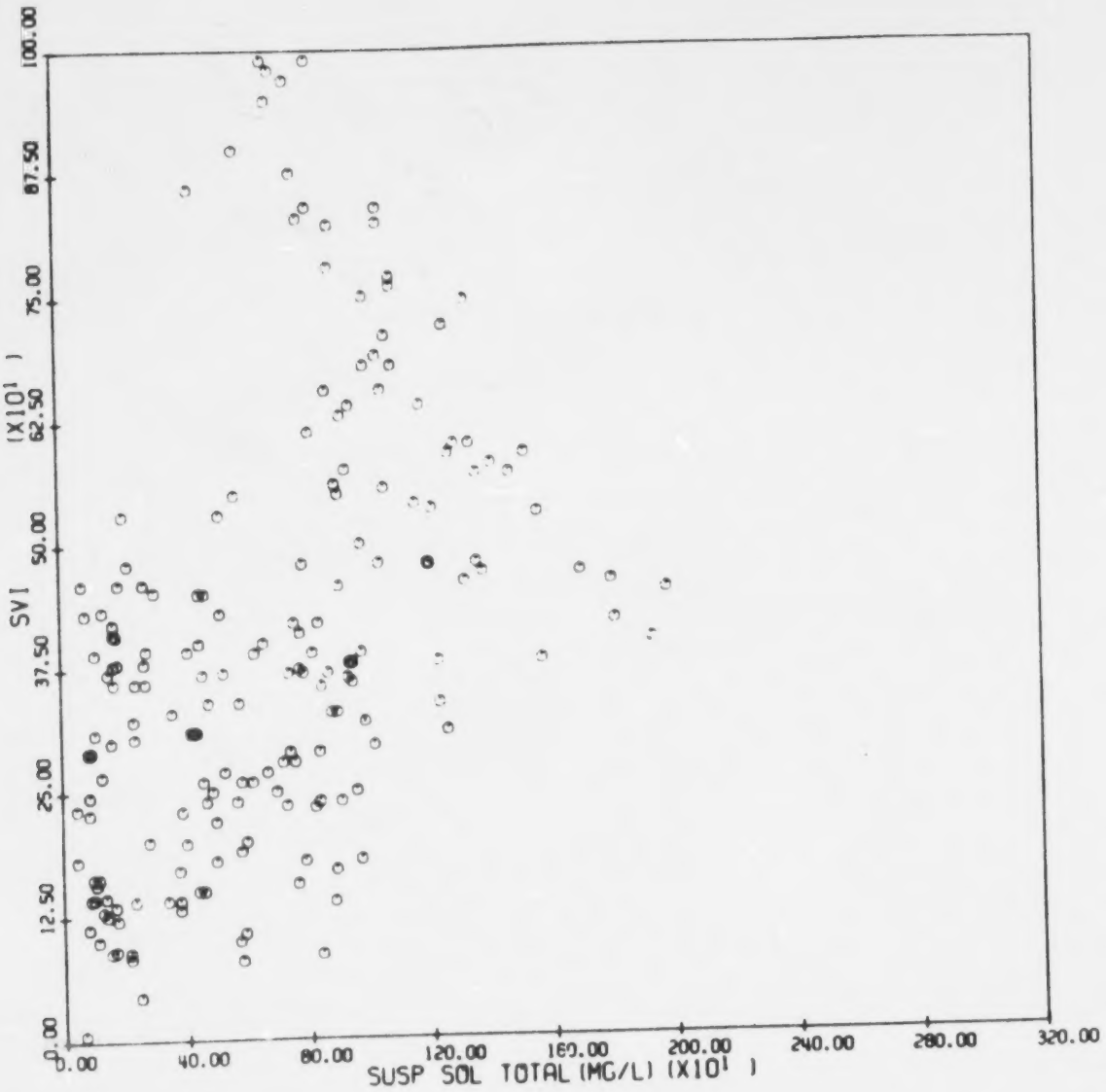

Figure 22. Sludge volume index versus effluent suspended solids (west).

The hydraulic characteristics of the straightline unit are shown in Table 17.

TABLE 17. DETENTION TIME AND OVERFLOW RATE FOR STRAIGHTLINE SETTLER

Flow, mgd	Detention Time, hrs.	Overflow Rate, gpd/sq.ft.
1.0	8.3	130
1.8	4.6	240
2.2	3.7	290
2.6	3.2	340

The overflow rates are quite low. An analysis of effluent suspended solids versus flow rate (Figure 23) did not show any correlation.

As was noted earlier, the flow through this unit caused turbulent conditions in the sludge hopper area and resulted in re-suspension of settled solids. The cage rotor also was not adequate to re-suspend the solids that had settled to the floor beyond the collector. A side door was installed near the effluent weir trough to permit periodic hydraulic scouring of the settled solids. This intermittent operation plus poor door seals created poor settling conditions in the unit and solids were carried over the weir with the final effluent.

The new inlet has been located near mid-length of the unit. This has improved the performance but it still is inadequate. A revised tank design has been proposed incorporating a new sludge removal system and eliminating the door to the aeration channel.

Although the organic loadings varied considerably, there was no significant correlation between total BOD_5 removal and organic loadings. The relationship of volumetric loading and loading factor to the percent removal of BOD is presented in Figures 24 and 25. The operational characteristics of the system and the high organic loadings of proteinaceous wastewater resulted in an increase in ammonia nitrogen and high effluent levels. As noted earlier, these levels are of concern and are affected by various factors.

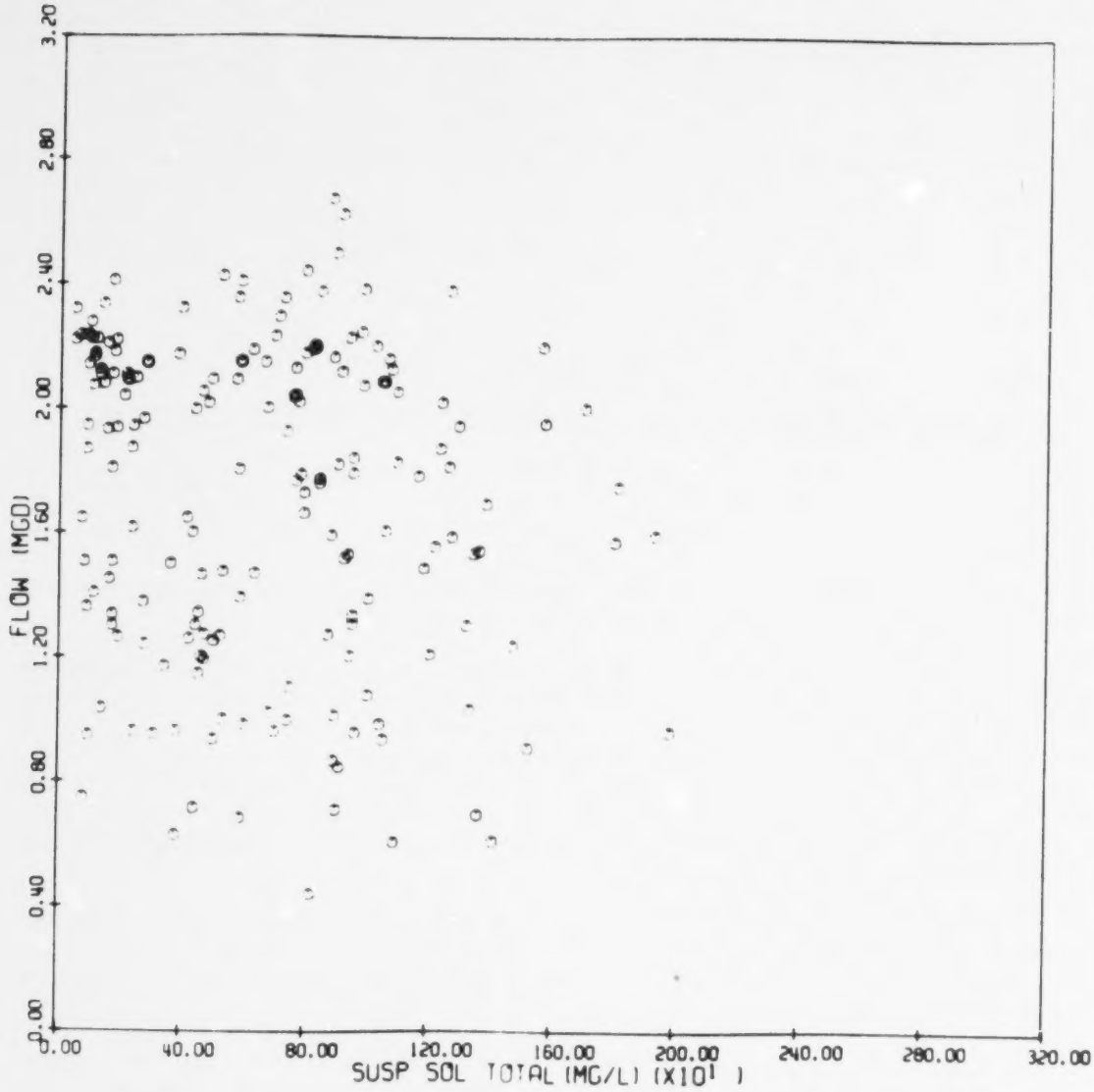

Figure 23. Flow rate versus effluent suspended solids (west).

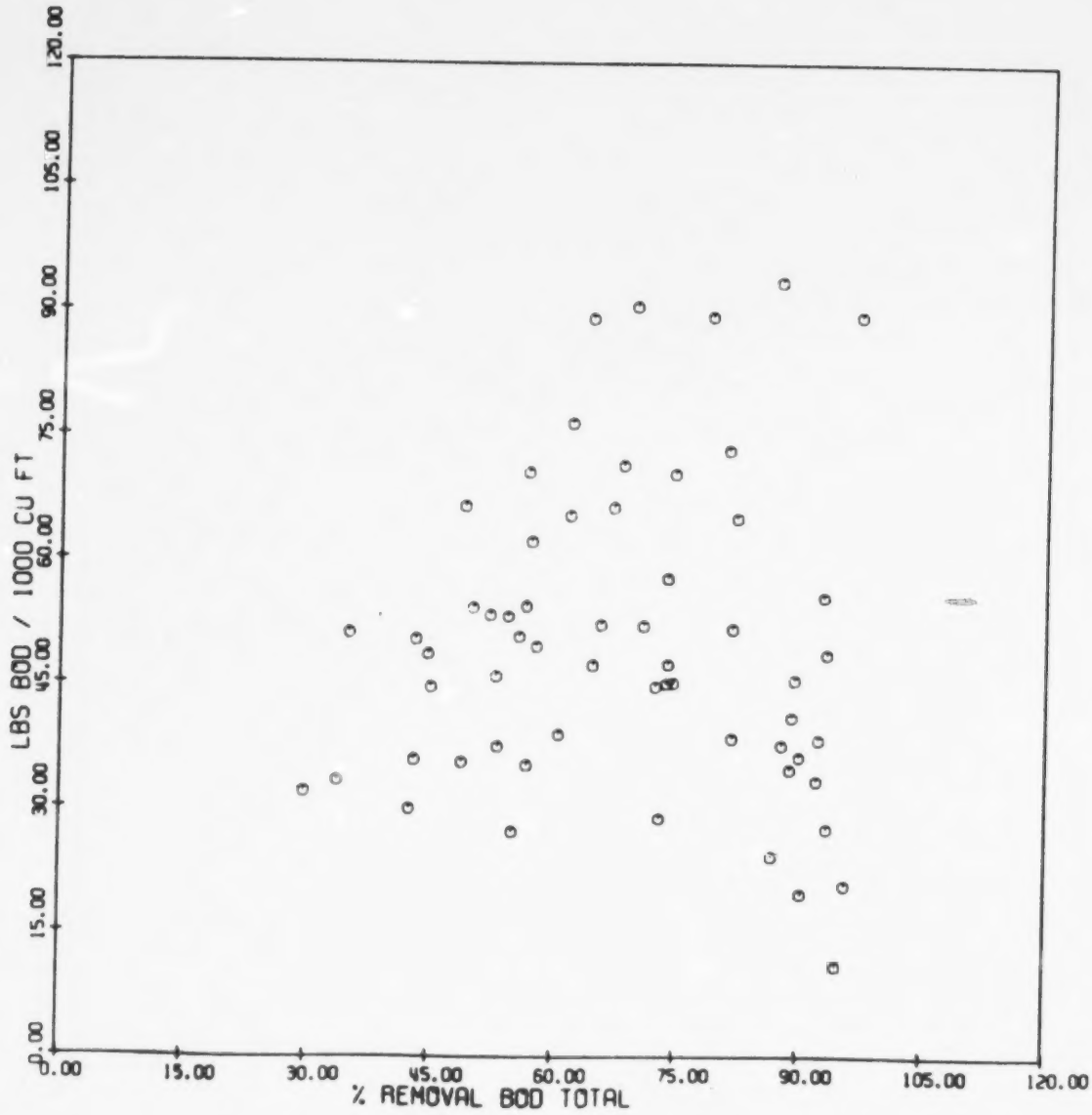

Figure 24. Volumetric loading versus removal BOD (west).

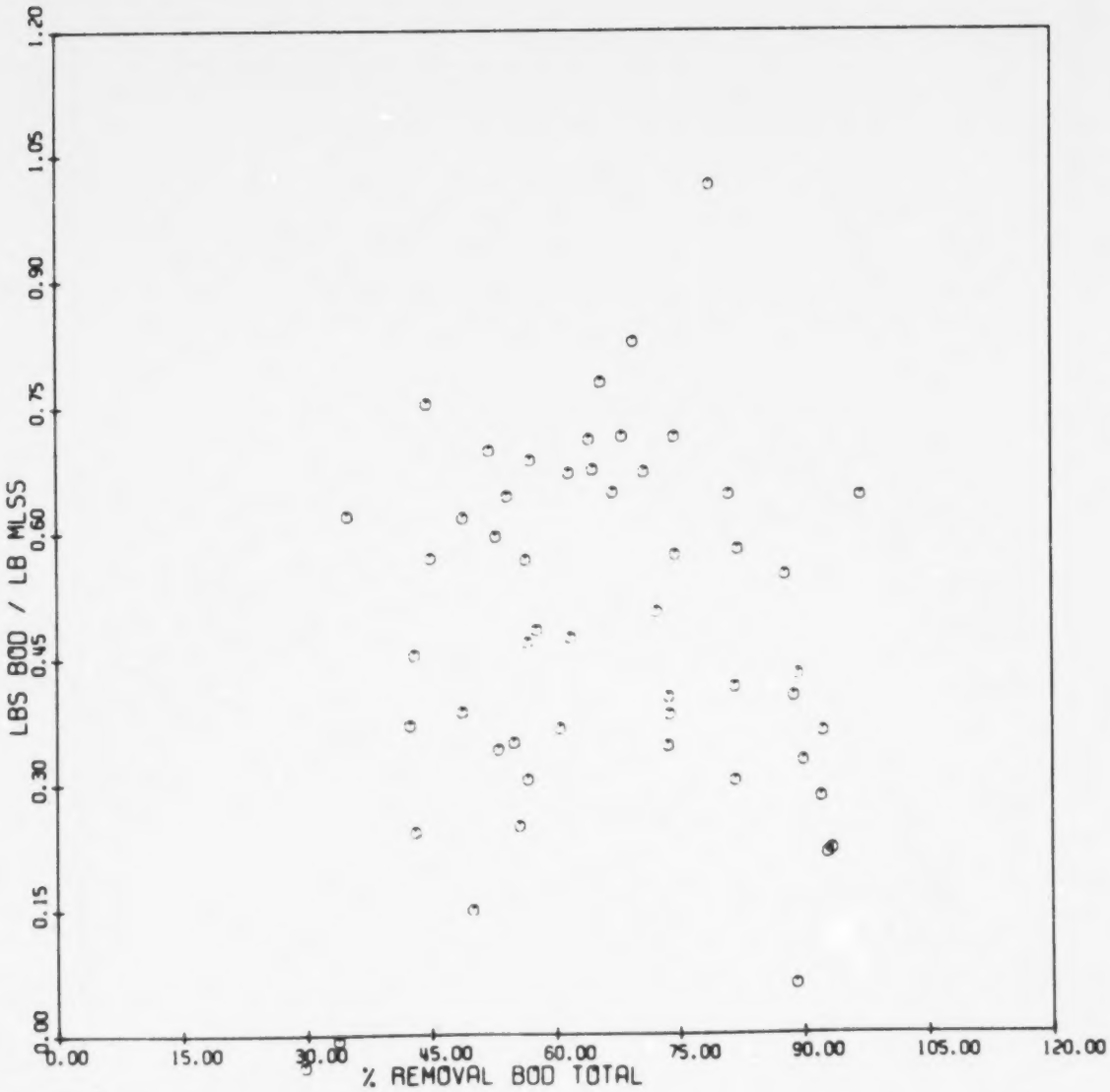

Figure 25. Loading factor versus percent removal BOD (west).

The floating aerator system was utilized in a non-standard application. The magna rotors were rated at 4.8 pounds per foot per hour (tapwater, 0.0 dissolved oxygen, 20 degrees C) for 10.5-inch immersion and a rotor speed of 68 revolutions per minute. The west aeration channel also generally operated at a steady-state oxygen level during weekday processing operations. Higher weekend dissolved oxygen levels were reached in the west channel. Based on a median channel BODs loading of 22,600 pounds per day and 98.1 percent removal (Total-Filtrate in Table 16) the west channel aeration system satisfied an oxygen demand of 22,150 pounds per day.

The overall removal efficiencies (unfiltered samples) for the west aeration system are much lower than the east channel due to the performance of the straightline settler. However, settling column studies indicated the effluent quality of the west channel would likely be similar to that of the east channel with the same type of settling system.

AERATION SYSTEM ANALYSIS

It would be desirable to analyze the oxygen transfer efficiency of the aeration system. The lack of equipment ratings and several aspects of the actual operation make any analysis uncertain.

The oxygen transfer of the magna rotors (west channel) was rated at 4.8 pounds per hour per foot of rotor at 10.5-inch immersion and 68 revolutions per minute. No ratings were available for the newly designed mini-magna rotors used in the east channel. The 20-horsepower floating aerators were rated at 1,400 pounds of oxygen per day and the 50-horsepower units at 3,000 pounds per day. (Note: The above ratings are at zero dissolved oxygen in tapwater at 20 degrees C).

The application of the floating aerators to this tank geometry (6-foot water depth, 40-foot channel width) did not correspond to the manufacturer's recommended installation. In addition, the drum on the 50-horsepower unit collapsed and was replaced with a shorter drum length.

The rotor aerators caused high flow velocities in the channels. Surface velocities exceeding 2.5 feet per second were observed. The manufacturer re-reported that only a part of the design rating can be achieved if velocities are significantly higher than 1.0 foot per second. In addition, when analyzing the oxygen demand satisfied, there were periods when some aerators were not operating.

The facilities were not designed nor evaluated to accurately determine transfer efficiencies. The following are the best estimates possible. If one assumed a transfer rate of 3,400 pounds per day for the floating aeration portion and utilized the satisfied oxygen demands as noted above of 11,670 pounds per day (east) and 22,150 pounds per day (west) the magna rotors transfer rate would be 4.3 pounds per hour per foot (180 feet operating) and the mini-magna rate would be 2.3 pounds per hour per foot (150 feet operating). The power consumption of the rotor aerators was not monitored separately, therefore horsepower values are not available. Using

manufacturer's data for the magna rotor (1.38 horsepower per foot), the magna rotor rating would be 3.1 pounds per horsepower-hour per foot of rotor.

SECTION 9

FINANCIAL CONSIDERATIONS

CONSTRUCTION COSTS

The total capital costs for construction (1970) of the wastewater treatment facilities was $983,321.00. A detailed cost breakdown is presented in Table 18.

OPERATION AND MAINTENANCE COSTS

Operation and maintenance costs for the facility during the demonstration period during 1971 were $82,224.00. Similar monthly expenses were experienced during 1972. A detailed breakdown is provided in Table 19. About 10 percent of the total operation and maintenance costs are the result of additional data collection and analysis required by the demonstration project.

An analysis based on the power requirements for the total plant operation yielded the values shown in Table 20. (This includes aeration, pumping, lighting and the operation of other plant equipment.)

Solids disposal costs were low during the study period because the grit and sedimentation unit sludges were disposed of to a company-owned landfill and waste activated sludge was discharged to the river. Projected annual costs for solids disposal including capital costs are $46,600. Land disposal will be used preceeded by air flotation, centrifugation and drying.

TOTAL ANNUAL COSTS

Total annual treatment costs can be viewed as the sum of (1) annual capital amortization costs (6 percent for 20 years) and (2) annual operation and maintenance costs. Some analysts include an annual equipment repair and maintenance cost estimated at 3 percent of equipment capital cost. Table 21 shows the treatment costs during the 1971-1972 demonstration period. The breakdown includes demonstration costs, since they constituted only a small percentage of the total costs. The waste load during the study period was 835,000 pounds of BOD and 82 million gallons per month, respectively.

The R. T. French Company (R. T. French Company. Aerobic Secondary Treatment of Potato Processing Wastes. Water Quality Office, US Environmental Protection Agency. Report No. 12060 EHV WPRD 15-01-68. 1970) reported annual

TABLE 18. CONSTRUCTION AND EQUIPMENT COSTS

Item	Cost
Earthwork	$ 45,500
Caissons	6,500
Structural concrete	104,500
Channel concrete	188,000
Reinforcing materials	15,500
Masonry and precast slabs	4,800
Buildings, miscellaneous (roof, doors, paint)	11,000
Miscellaneous metals (rails, walkway, motor covers, etc.)	62,000
Interior piping and valves	38,000
Exterior piping	31,000
Plumbing, heating, ventilation	12,000
Fencing	3,000
Electrical	69,500
Rotor shields	22,500
Plant equipment	
Grit aeration	7,400
Primary sludge collector	20,500
Grit and sludge conveyors	14,250
Raw sewage pumps	11,500
Sludge pumps	4,800
Instrumentation and flumes	5,800
Samplers	4,430
Fixed rotor aerators	110,690
Floating aerators	31,815
Circular clarifier	13,300
Laboratory equipment	7,500
Technical services	
Preliminary studies and report	19,889
Plans and specifications	19,647
Supervision of construction	22,000
Post construction studies	46,000
Legal and fiscal	10,000
Administration	20,000
Total	$983,321

TABLE 19. OPERATION AND MAINTENANCE COSTS - 1971

Item	Cost
Salaried (2 operators, 1 chemist)	$45,127
Overtime, travel	3,272
Power	29,048
Consultant fees	2,971
Laboratory supplies	1,806
Total	$82,224

TABLE 20. POWER REQUIREMENTS

Parameter	90%	Median	10%
Kilowatt hours per pound BOD applied to aeration system	0.52	0.21	0.03
Killowatt hours per million gallons per day - total flow	4,591	1,936	475

treatment costs for an activated sludge plant at 0.038 cents per pound BOD applied. Michael (Michael, R. L. Cost and manpower for municipal wastewater treatment plant operation and maintenance, 1965-1968. Journal Water Pollution Control Federation. 42:1883. 1970) reported annual operation and maintenance costs for activated sludge plants (secondary treatment only) ranging from 0.0175 cents to 0.087 cents per pound of BOD applied. The annual treatment costs at John Morrell and Company during the study period, 0.0168 cents per pound BOD applied, are quite low in comparison. Reported costs for other food processing waste treatment operations range from 0.04 cents to 0.06 cents per pound of BOD applied.

The lower costs at John Morrell and Company are probably due to the lower total labor costs, the method of solids disposal and the cost advantage associated with treatment of large waste loads. Adding the extra capital cost and operation and maintenance costs for solids handling and disposal would result in total wastewater treatment costs of about 0.02 cents per pound of BOD applied (0.33 cents per 1,000 pounds LWK).

TABLE 21. TREATMENT COSTS

Item	1971	First half 1972
Amortized capital cost	$ 85,725	$42,862
Operation and maintenance cost	82,224	37,875
Total	$167,949	$80,737
Estimated cost of treatment:		
10,000,000 lbs BOD/year	$0.0168 per lb BOD applied	
19,400,000 lbs COD/year	0.009 per lb COD applied	
984,000,000 gallons/year	0.171 per 1,000 gallons of flow	

SECTION 10

WASTE ACTIVATED SLUDGE UTILIZATION

CHARACTERISTICS AND TREATMENT

The quantity and quality of the sludge varied throughout the study as noted in the channel discussions. The waste sludge evaluated varied in initial solids content from 0.3 to 0.6 percent. Pilot studies of thickening included air flotation and centrifugation.

A pilot model air flotation unit (EIMCO) with a design flow rate of 30 gallons per minute was used. With a 50 to 60 percent effluent recycle, the waste sludge volume flow rate is reduced to 15 gallons per minute. In a study with a feed sludge concentration of 0.3 percent, the float was 2.5 to 3 percent and the underflow 0.03 to 0.05 percent solids.

Two separate centrifugation studies were performed, one with a scroll-type bowl and the other a basket-type bowl. The sludge cake yield was too low and of poor quality with the scroll-type unit. Sludge samples of feed to and from the pump showed a straining effect and required a greater flocculation time. These factors affected the centrifuge performance.

A 12 by 6 inch solid bowl centrifuge performed very well on settled waste sludge; high recoveries and very high cake concentrations were achieved without the use of chemicals. The sludge was fed to the unit using a centrifugal pump. The results of six runs made at different flow rates at 1,300 G (gravity forces) are shown in Table 22.

The data indicates that a basket centrifuge can effectively concentrate waste activated sludge from the oxidation ditch process. At moderate feed rates concentration of the cake is not affected by feed concentration. The data will not be used to size units for the operation since pre-thickening by air flotation or other means is essential from an economic viewpoint.

ANIMAL FEED SUPPLEMENT

The project objectives included an evaluation of the use of waste activated sludge as an animal feed supplement due to its predicted high protein content.

Several samples of waste activated sludge were collected and analyzed. The sludge was dried, then analyzed for specific constituents. The nitrite

TABLE 22. BASKET CENTRIFUGATION OF WASTE ACTIVATED SLUDGE

Feed		Cake solids, %	Solids recovery (%) versus time			
gpm	% solids		5 min.	10 min.	15 min.	20 min.
1	0.5440	9.3	89	88	87	82
1.5	0.5410	7.8	87	84	73	48
2	0.5230	8.5	84	79	48	-
2	0.2965	9.0	87	81	80	81
3	0.3990	9.3	66	67	55	49
4	0.3760	8.3	49	46	37	35

and nitrate content was zero or less than 0.1 percent. The results are presented in Table 23.

Protein evaluation tests were made on three different samples of dried sludge. In these tests, 0.24 grams of nitrogen per day is fed to a set of five rats over a five-day period. The weight gain in grams during the five-day period is an accepted measure of the value of the protein as feed supplement. A value of 2 to 8 is considered equivalent to a high grade tankage. A value of 8 to 12 is equivalent to meat scraps fortified with blood. The higher the value, the more complete is the amino acid complement. The results are shown in Table 24.

The first two samples were collected coincident with normal packinghouse operation. The last sample was collected when the hog operation was down. All three values indicate a good source of protein, but suggest a deficiency in at least one of the essential amino acids.

Based upon positive possibilities from the protein evaluation studies, a rat feeding study was performed. Sludge collected during centrifugation tests was oven dried and blended with sodium caseinate and other standard feed ingredients. The rats used for the study were from an in-house rate colony. The test animals were raised, selected and fed the mixture under standard controlled conditions. Analysis of the sludge is shown in Table 25.

TABLE 23. COMPOSITION OF WASTE ACTIVATED SLUDGE

Component	Percent present		
	09/01/71	09/21/71	11/27/71
Protein	53.2	45.1	46.3
Moisture	7.1	5.1	1.4
Fat	9.3	20.0	19.9
Fiber	5.2	2.5	-
Ash	13.2	14.6	13.7
Calcium	1.7	-	1.8
Phosphorus	1.8	-	1.3

TABLE 24. PROTEIN EVALUATION TESTS

Date	Protein value	Salt content, %
3/25/71	5	14.8
4/7/71	8.4	6.4
5/13/71	3.5	0.8

TABLE 25. COMPOSITION OF SLUDGE

Constituents	Percent
Moisture	5.1
Crude protein	45.1
Crude fat	20.0
Crude fiber	2.5
Ash	14.6
Salt	1.7
Nitrogen free extract	12.7
Calories per pound	18.7

The actual diet was prepared to provide a finished protein content of 10 percent and a fat content of 5 percent. This was to eliminate variations of the caloric value with the only variable being the kind of protein in the diets. Results from the feeding test are presented in Table 26.

The results indicate that use of 25 percent sludge in the total protein of a feed would produce good feeding results. Survival and net gain by all of the animals on the 100 percent sludge diet shows that all of the essential amino acids are present. The level, however, is not sufficient for normal expected growth. This is borne out by the level of gain at 50 to 75 percent sludge protein. A sample of sludge was analyzed for amino acids. The results are as shown in Table 27.

Based on this analysis, the sludge appears to have potential for replacing soybean meal in certain types of swine rations and layer rations. The methionine value is significant in that one pound of activated sludge would replace 1.5 pounds of soybean meal on a methionine basis.

These results indicate that the sludge is a suitable feed supplement, however, additional testing is necessary.

TABLE 26. RAT FEEDING TEST

Diet protein	Average weight gain, grams	Average food consumed, grams	Gram food/gram gain, 60 days	Efficiency 60 days, %
100% caseinate	168.5	752	4.53	22.3
25% sludge 75% caseinate	159.9	813	5.16	19.8
50% sludge 50% caseinate	136.3	795	5.87	17.1
75% sludge 25% caseinate	81.4	671	8.29	12.1
100% sludge	30.4	429	13.93	7.2

TABLE 27. AMINO ACID ANALYSIS OF ACTIVATED SLUDGE*

Amino acid	Percent
Lysine	1.65
Histidine	0.32
Arginine	1.25
Aspartic acid	3.73
Threonine	1.97
Serine	1.49
Glutamic acid	4.72
Proline	1.29
Cystine	0.35
Glycine	2.46
Alanine	3.10
Valine	2.10
Methionine	0.93
Isoleucine	1.53
Leucine	2.77
Tyrosine	2.21
Phenylalanine	2.45

*Total crude protein (N x 6.25), 44.80%.

SECTION 11

EFFLUENT CHLORINATION

A laboratory scale evaluation of the effluent chlorination requirements for this treatment system was conducted. The total and fecal coliform organism counts varied widely. It should be noted that most of the sanitary wastewater from plant operations is discharged to another sewer system. The results of a typical analysis (February 7, 1972) are noted in Table 28.

TABLE 28. TYPICAL COLIFORM RESULTS

Sample Location	Total Coliforms, number/100 ml	Fecal Coliforms, number/100 ml
48-inch sewer	4,700,000	2,800,000
Treatment plant influent	16,300,000	1,180,000
Treatment plant effluent	6,900,000	280,000

A series of experiments (Jar test apparatus) were conducted in December 1971 utilizing final clarifier effluents. The effluent sample quality and test results are presented in Table 29.

A free chlorine residual was obtained in almost all cases where the applied chlorine dosage was 15 milligrams per liter or greater. Organism reductions were very good, exceeding 99 percent, and in practically all cases the final effluent fecal coliform count was less than or equal to 10 organisms per 100 milliliters. Based on these tests, a chlorine dosage in excess of 10 milligrams per liter and a contact time of approximately 15 minutes would achieve excellent fecal coliform reduction. For this plant design a contact chamber would need to be added to achieve adequate contact time. The outfall sewer would only provide 5 to 7 minutes of contact time.

TABLE 29. FINAL EFFLUENT CHLORINATION

Run No.	Total coliforms, number/100 ml	Fecal coliforms number/100 ml	NH_3-N as N, mg/l	Suspended solids, mg/l	pH	Temperature, °C
A. Effluent Sample Quality						
I	240,000	107,000	19.2	136	7.6	13
II	120,000	22,000	10.2	92	7.4	10
III	360,000	49,000	10.2	216	7.4	11
IV	520,000	55,000	12.5	134	7.3	12
V	240,000	32,000	11.8	128	7.3	12

Run No.	Contact time, min.	Applied, mg/l	Total residual, mg/l	Free residual, mg/l	Total coliforms,* number/100 ml	Fecal coliforms, number/100 ml
B. Test Results - Chlorine†						
I	20	5.3	2.2	0.0	1,010	50
		10.6 to 26.6	5.3 to 18.4	0.0 to 0.8	$\leq$ 10	$\leq$ 10
	15	10.6 to 26.6	6.0 to 18.8	0.0 to 1.2	$\leq$ 10	$\leq$ 10
II	20	10.1 to 25.3	7.6 to 23.0	0.2 to 1.1	--	$\leq$ 10
III	10	15.2 to 25.3	14.4 to 22.5	0.2 to 1.1	--	$\leq$ 10
	30	5.1 to 15.2	1.6 to 17.5	0.0 to 0.2	--	$\leq$ 10
IV	20	5.1 to 20.2	2.9 to 17.1	0.0 to 0.2	$\leq$ 10	$\leq$ 10
V	20	5.1 to 20.2	2.6 to 17.1	0.0 to 4.6	$\leq$ 10	$\leq$ 10

*The 5.1 mg/l dosage tests in run numbers IV and V resulted in total coliform counts of 20/100 ml. All other tests were less than or equal to 10 organisms/100 ml.

†Except for run number I (20), a series of tests at various applied chlorine dosages were conducted.

SECTION 12

PERTINENT PUBLICATIONS

Ahrens, G. E. 1969. Morrell Pioneers More Efficient Aeration. Food Engineering.

Paulson, W. L., D. R. Kueck, and W. E. Kramlich. Oxidation Ditch Treatment of Meat Packing Wastes. Second National Symposium on Food Processing Wastes Proceedings, March 1971.

Paulson, W. L., L. D. Lively, and J. L. Witherow. Analysis of Wastewater Treatment Systems for a Meat Processing Plant. Twenty-seventh Annual Purdue Industrial Wastes Conference Proceedings, May 1972.

APPENDIX A

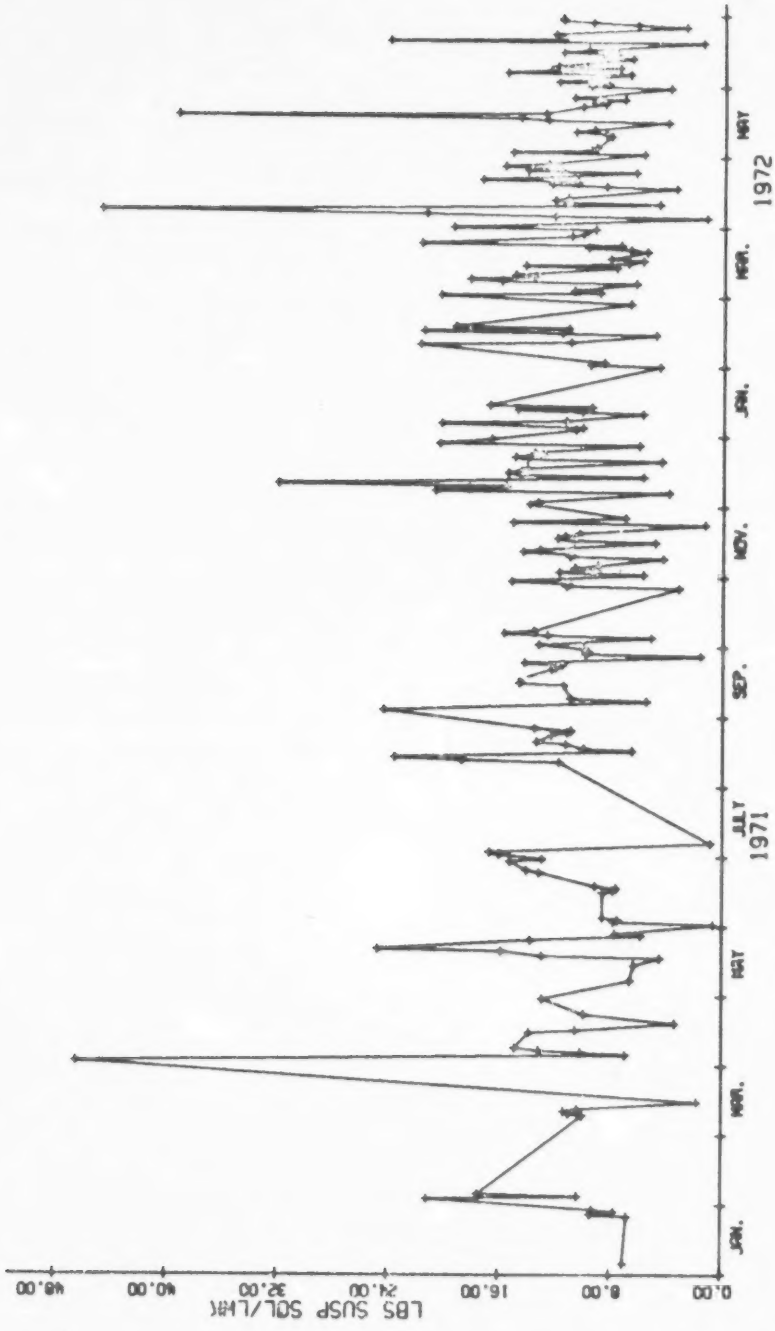

Figure A-1. Pounds suspended solids/live weight killed versus date (raw).

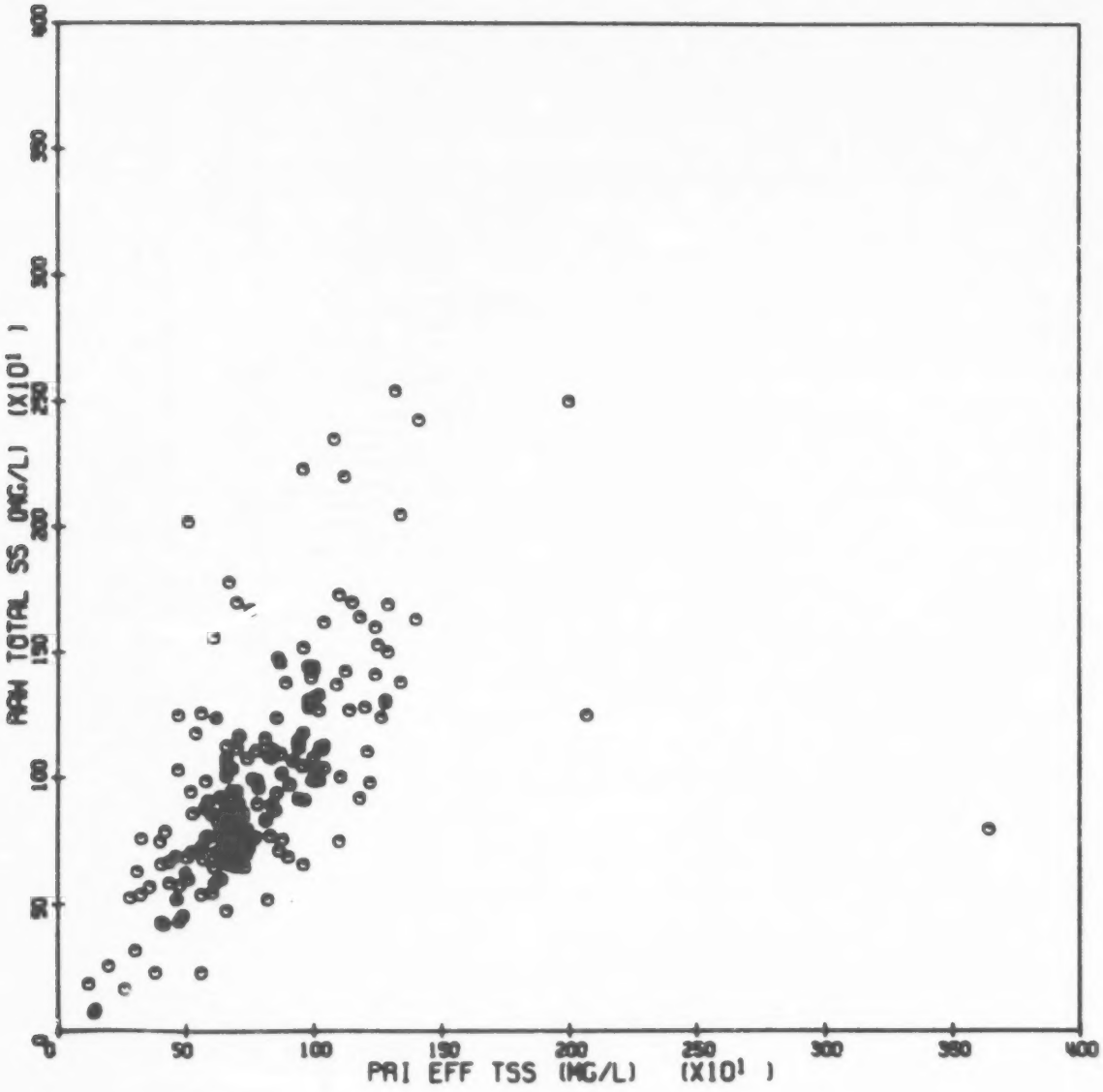

Figure A-2. Raw total suspended solids versus primary effluent total suspended solids.

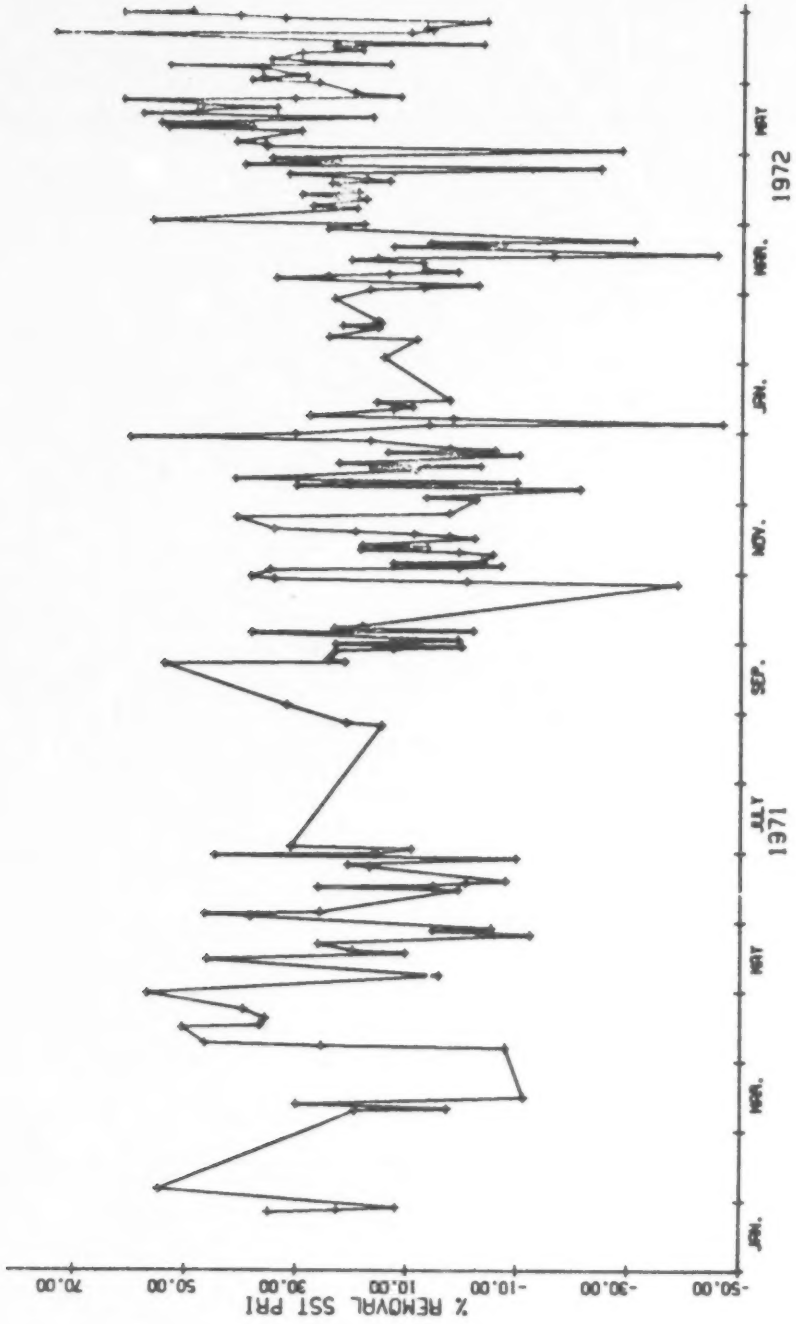

Figure A-3. Percent removal suspended solids versus date (primary).

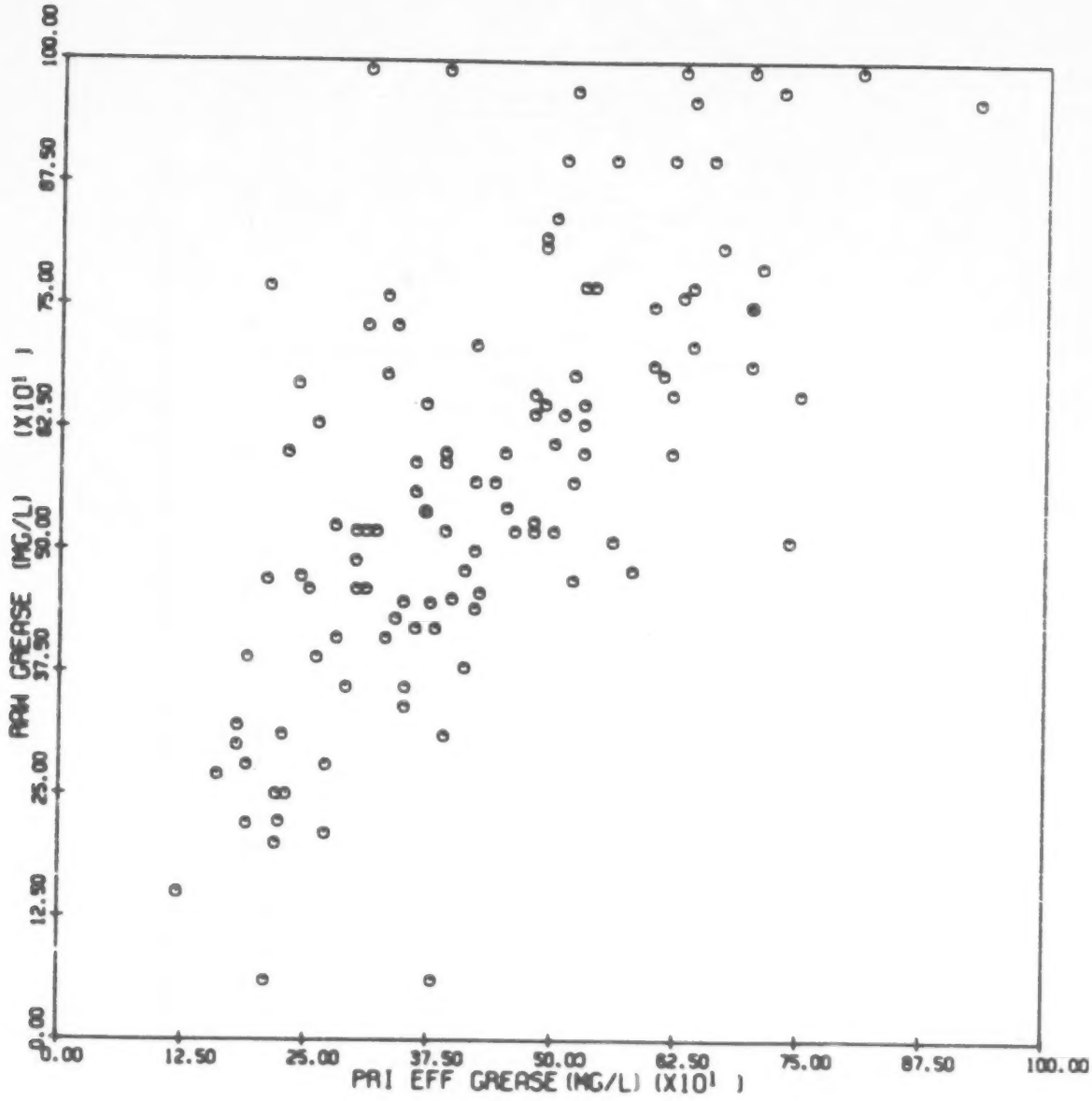

Figure A-4. Raw grease versus primary effluent grease.

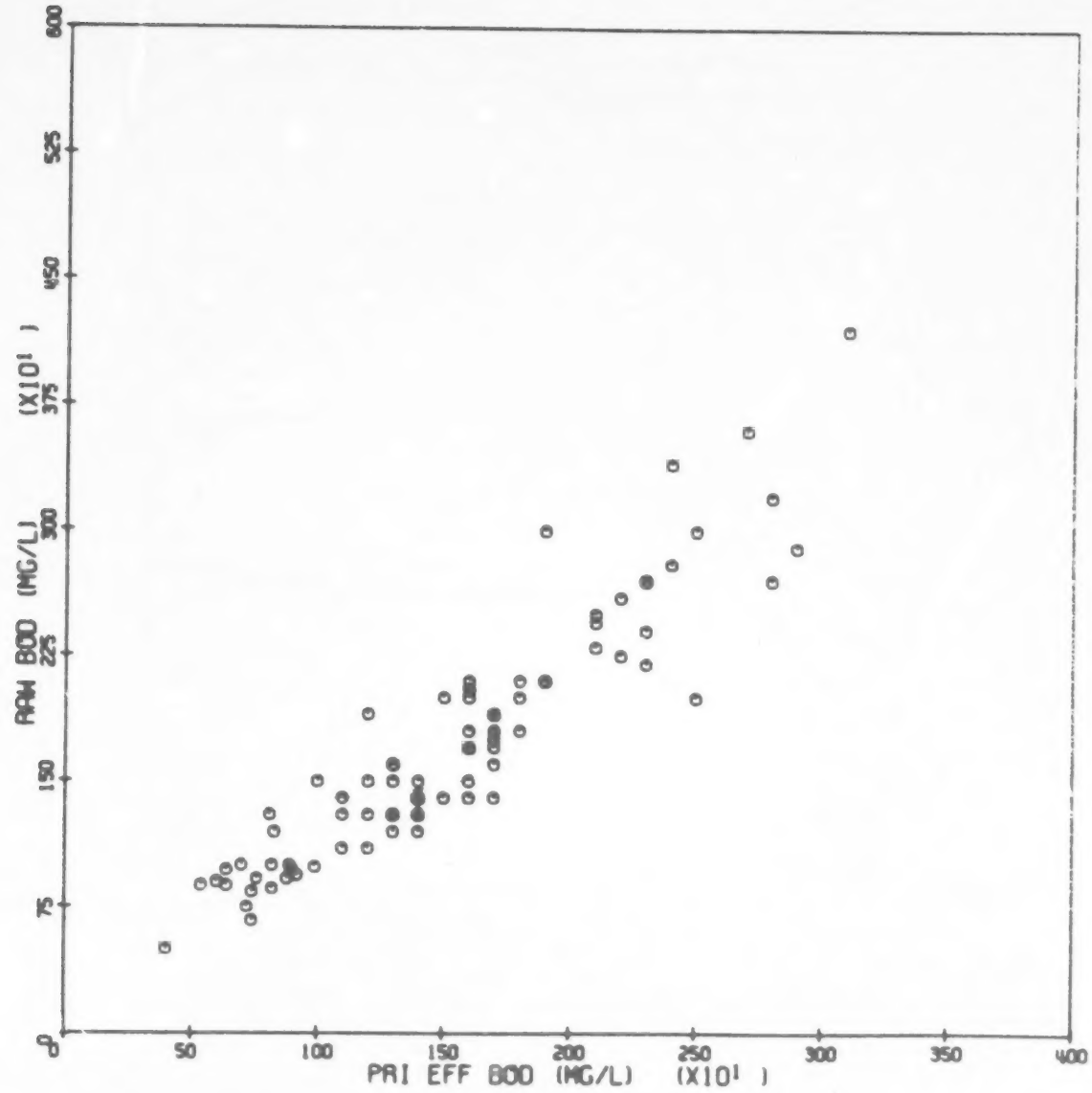

Figure A-5. Raw BOD versus primary effluent BOD.

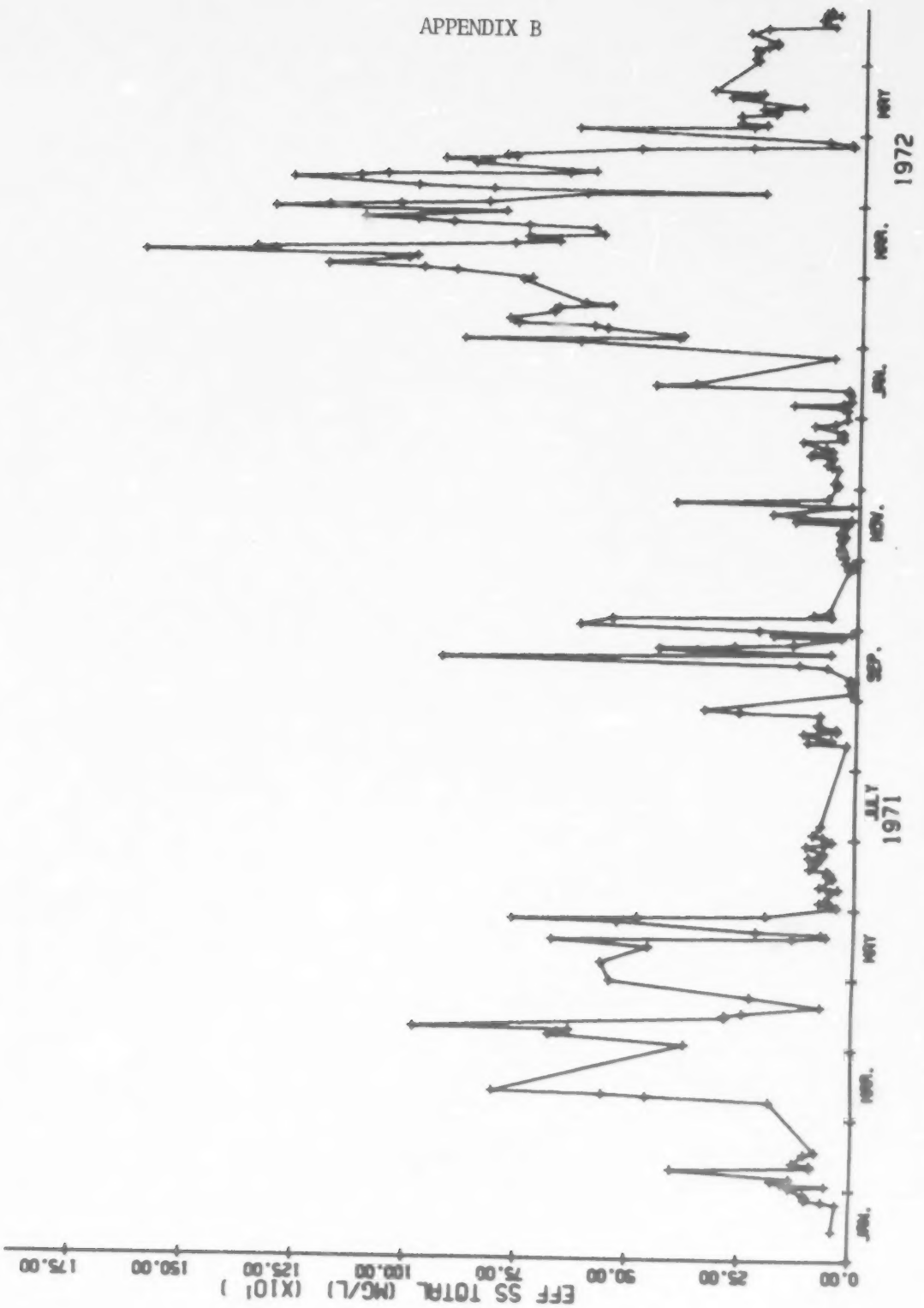

Figure B-1. East effluent suspended solids versus date.

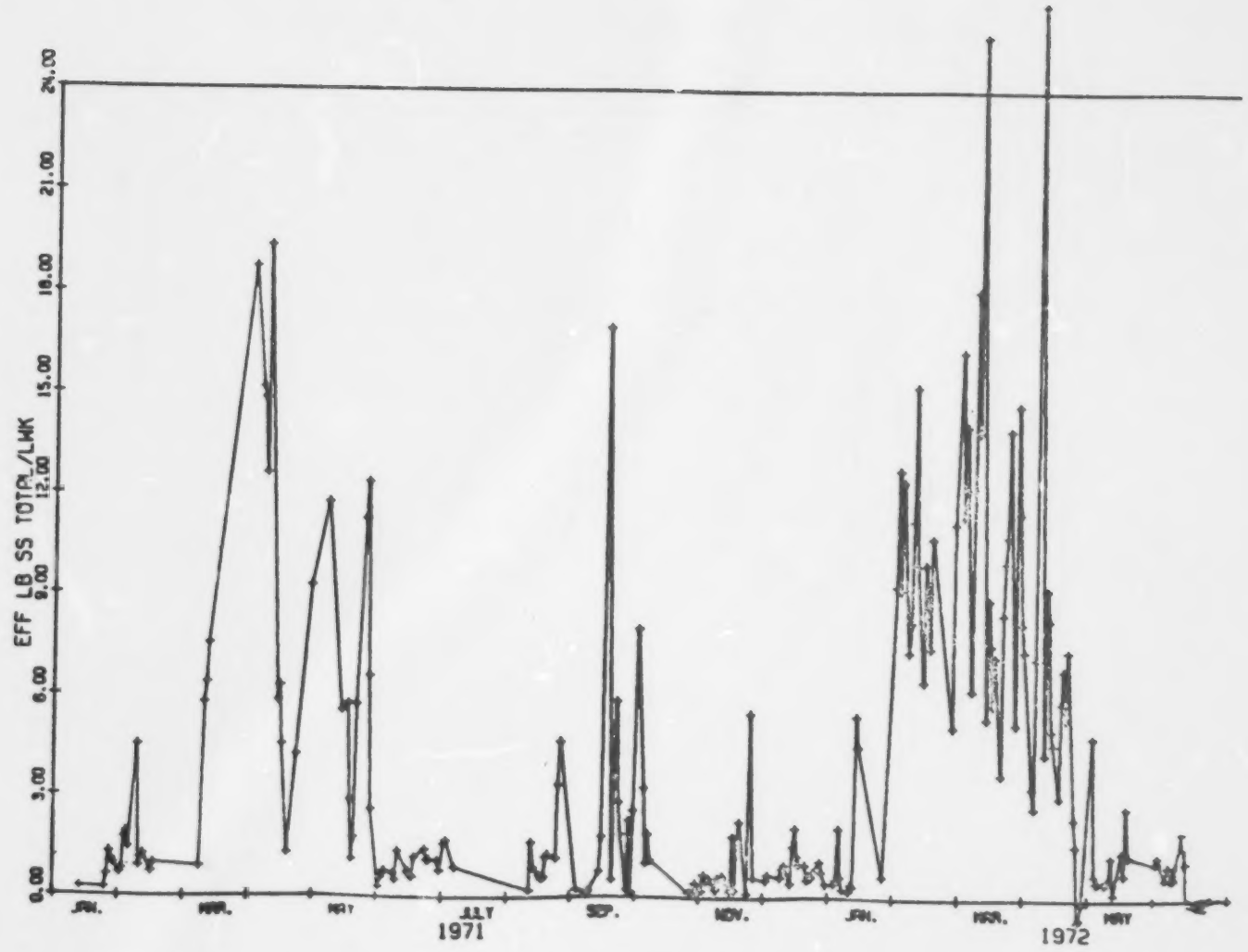

Figure B-2. East effluent pounds suspended solids/live weight killed versus date.

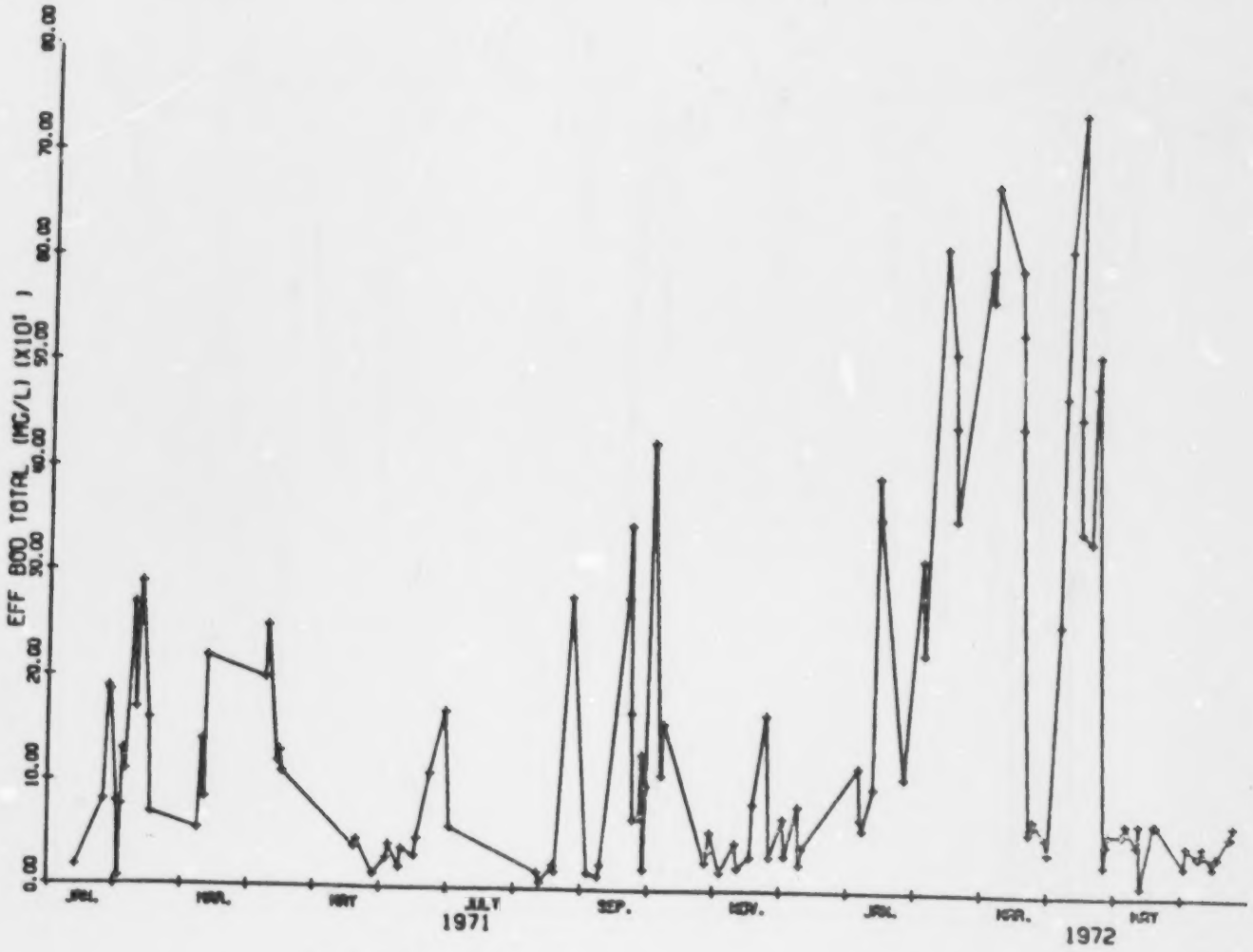

Figure B-3. East effluent BOD total versus date.

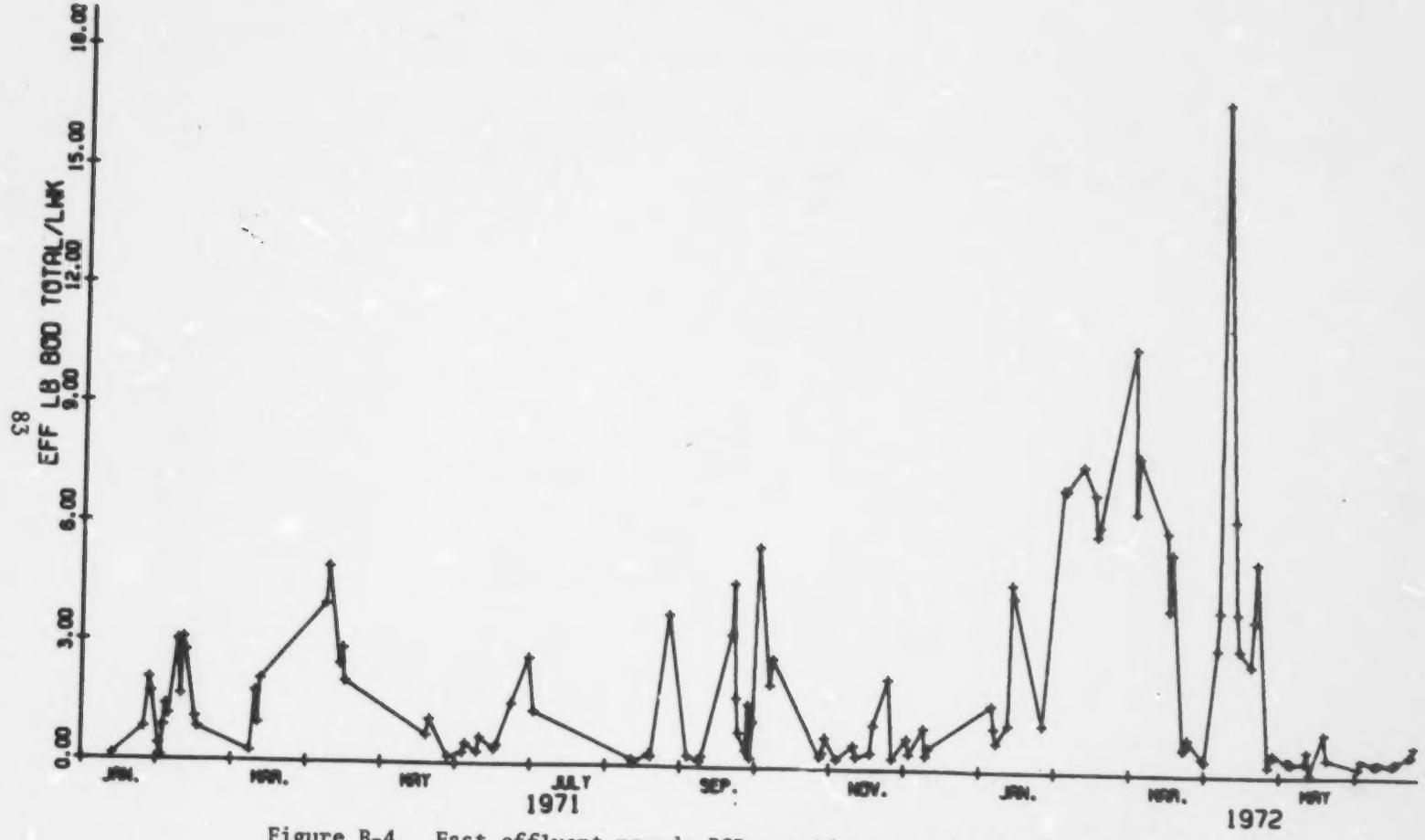

Figure B-4. East effluent pounds BOD total/live weight killed versus date.

APPENDIX C

Figure C-1. West effluent suspended solids versus date.

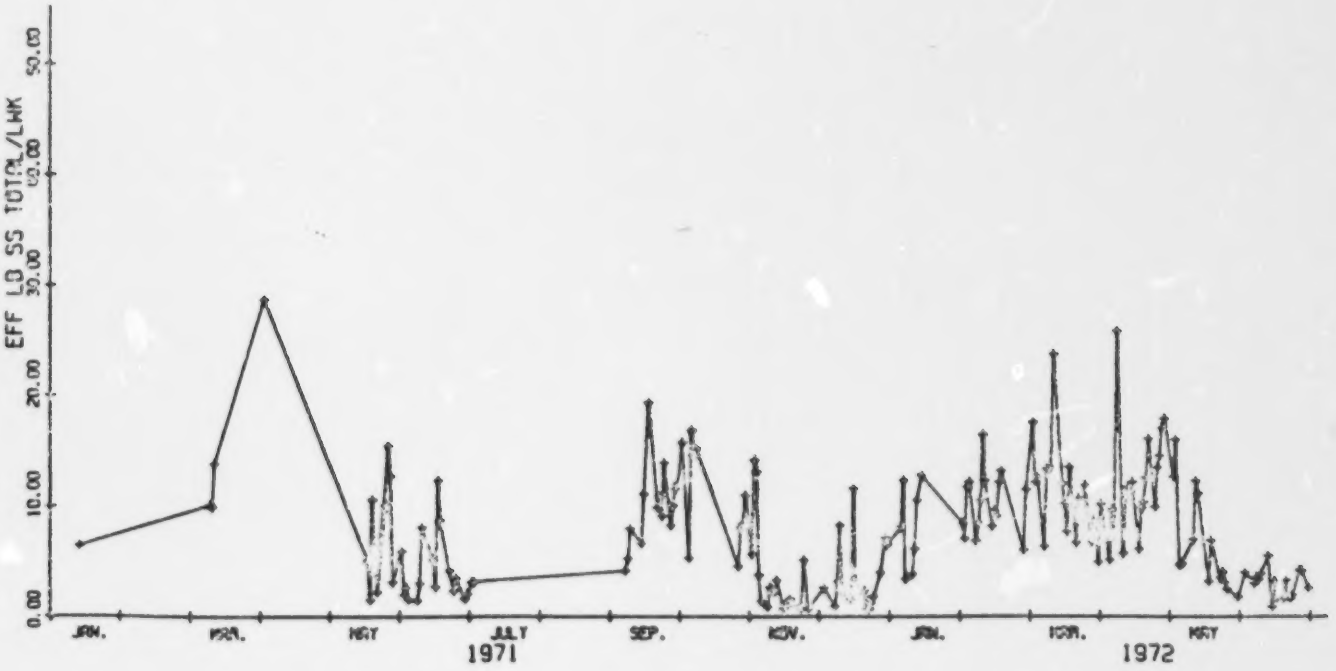

Figure C-2. West effluent pounds suspended solids/live weight killed versus date.

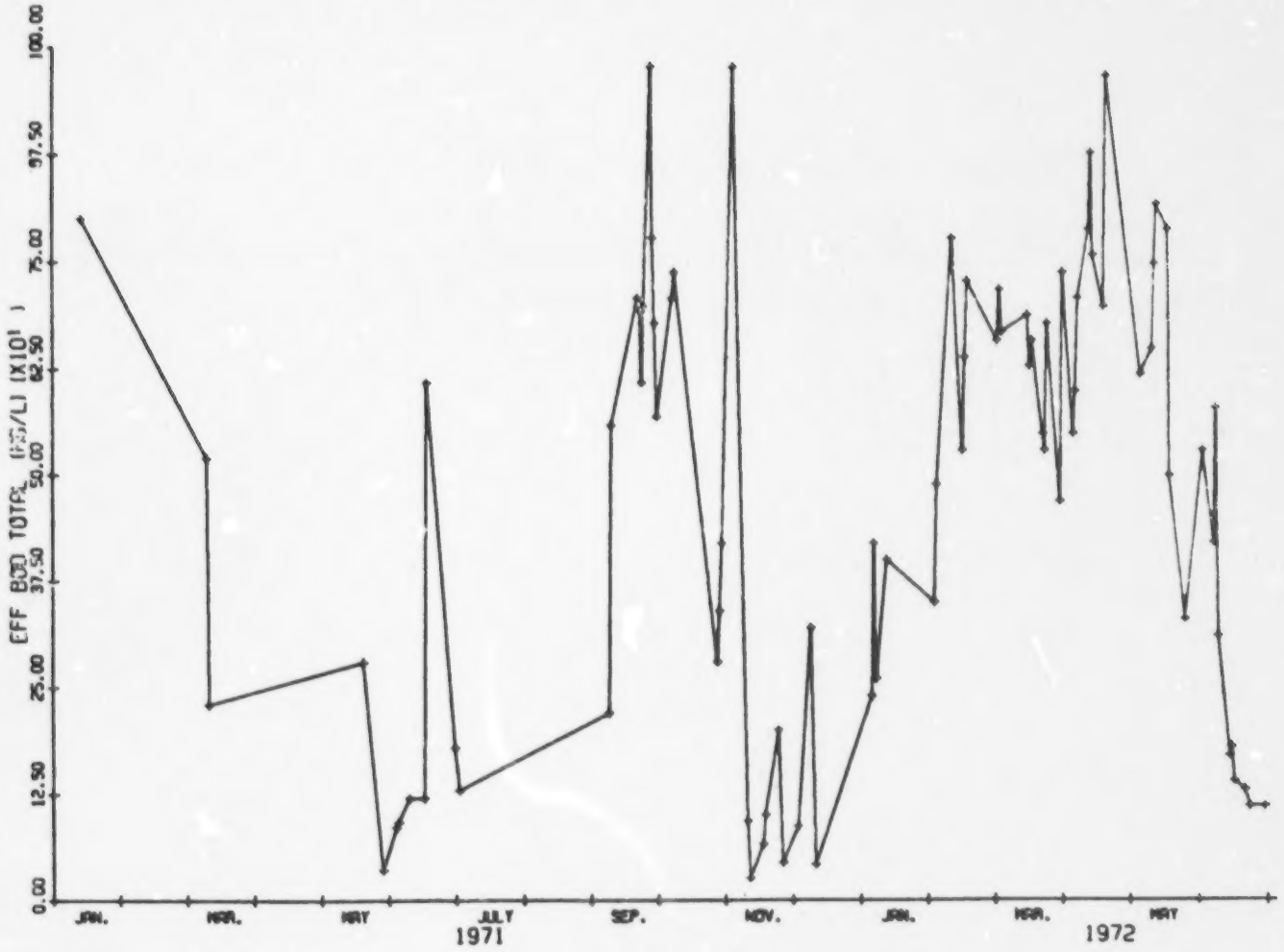

Figure C-3. West effluent BOD total versus date.

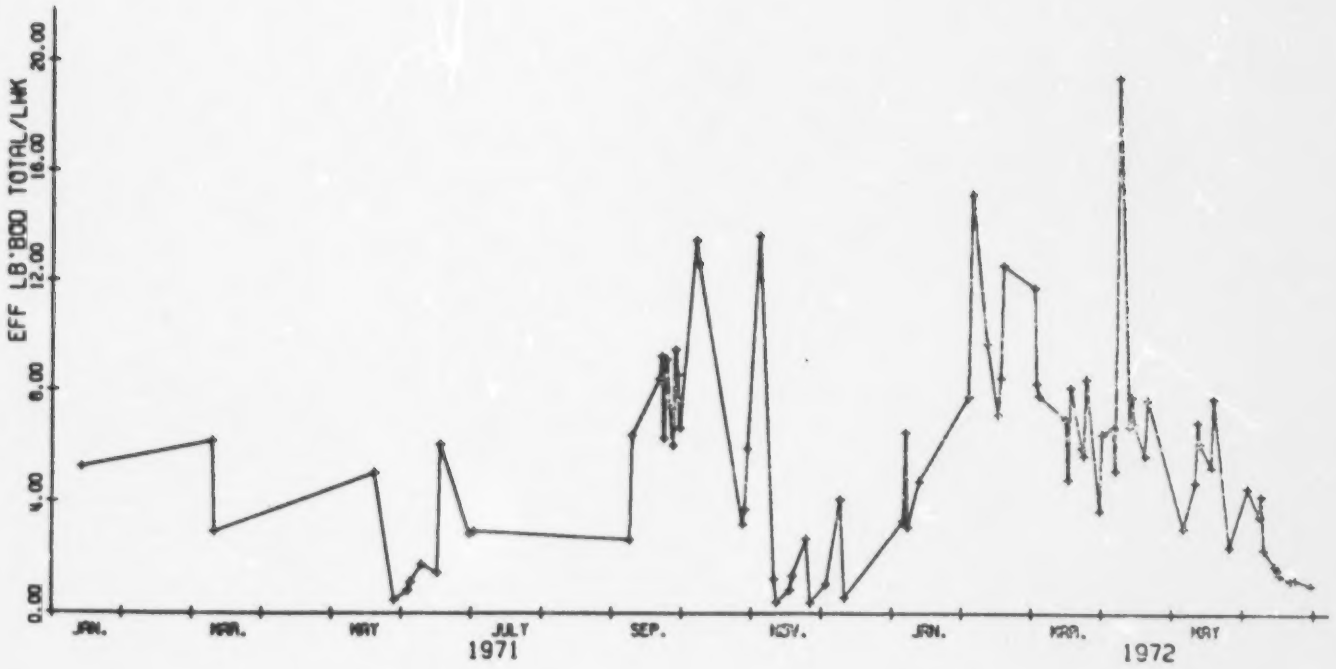

Figure C-4. West effluent pounds BOD total/live weight killed versus date.

APPENDIX D

Figure D-1. Plant site location.

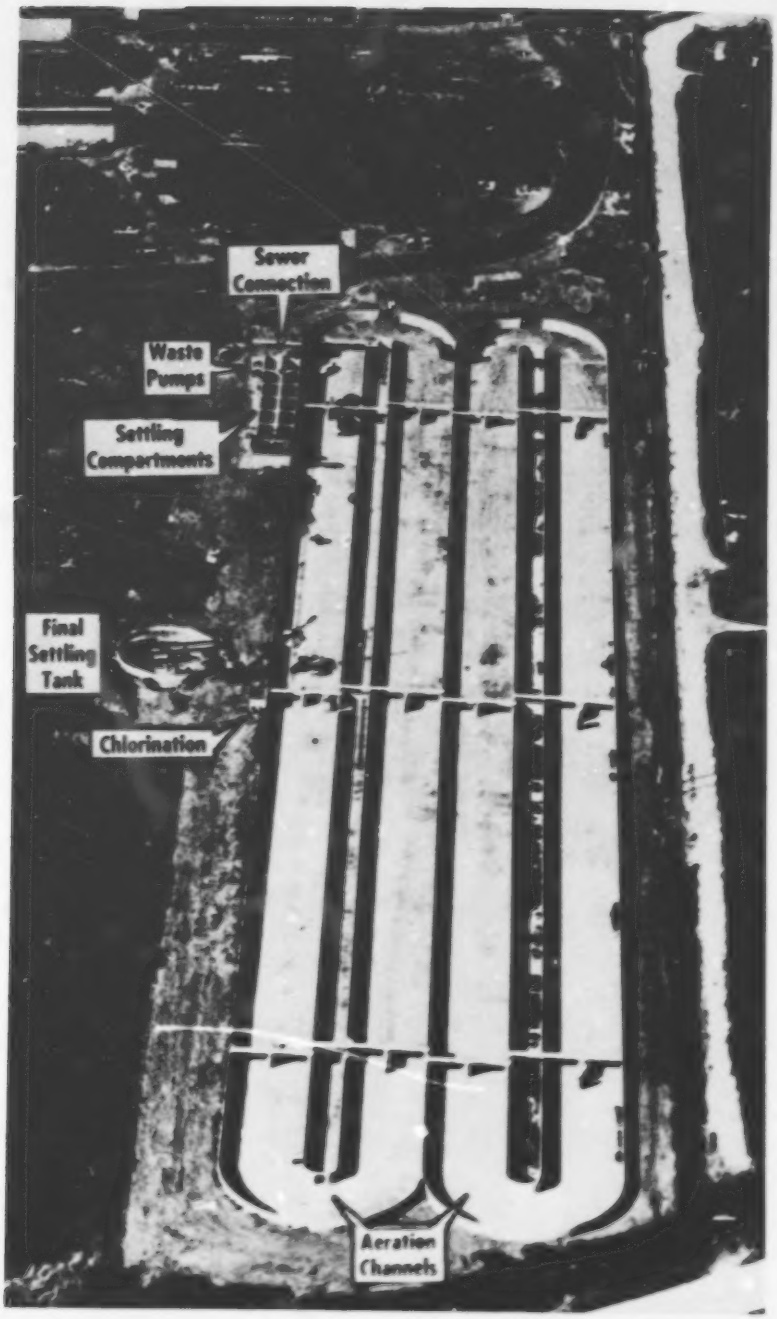

Figure D-2. Aerial view of treatment system in construction.

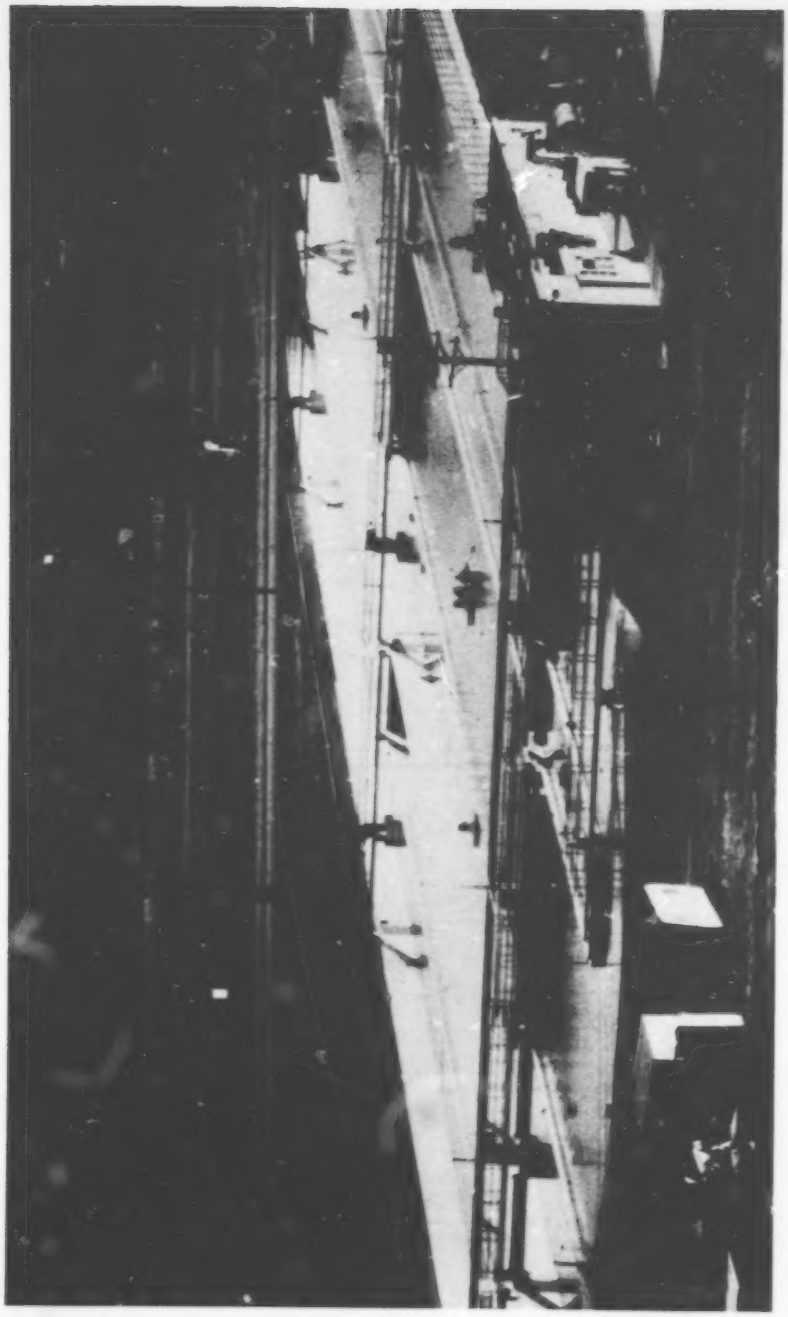

Figure D-3. Treatment plant.

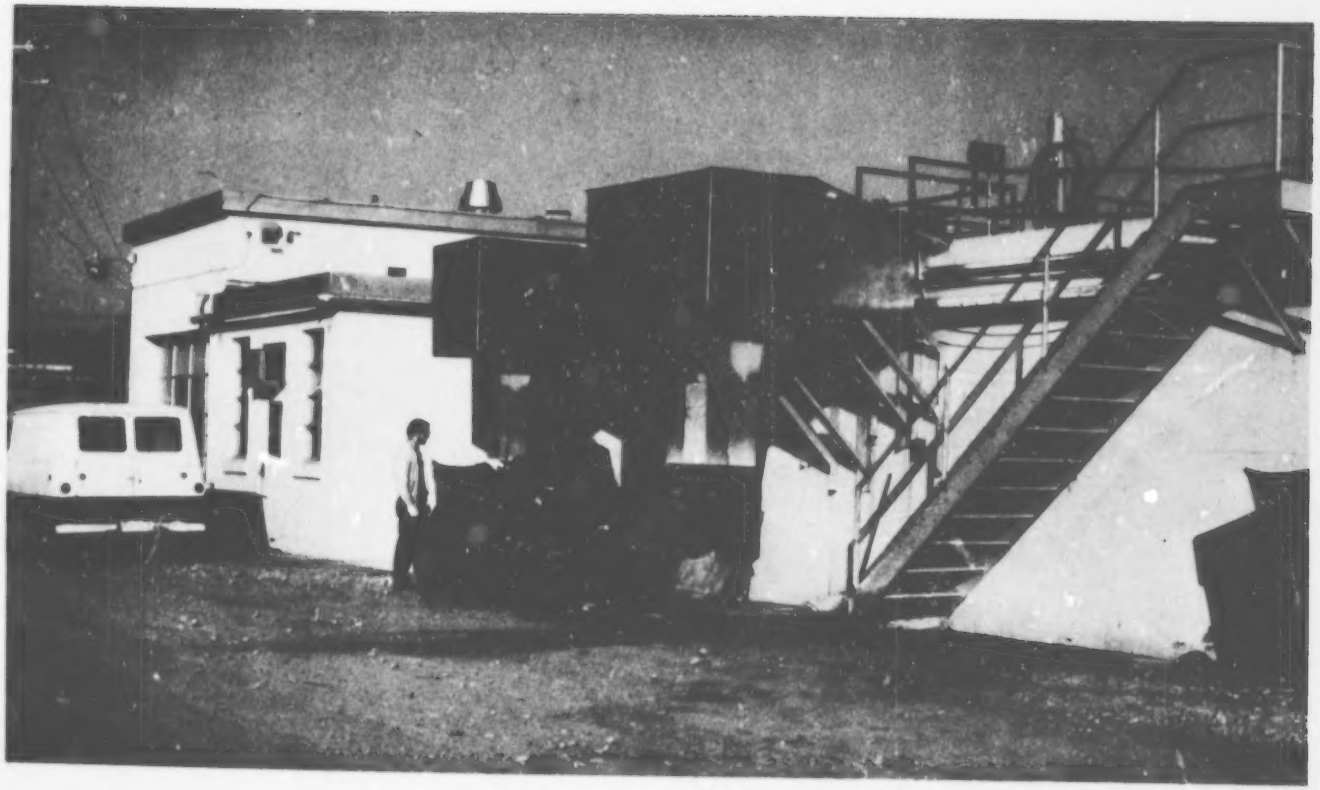

Figure D-4. Heating unit modification to tubular conveyor system.

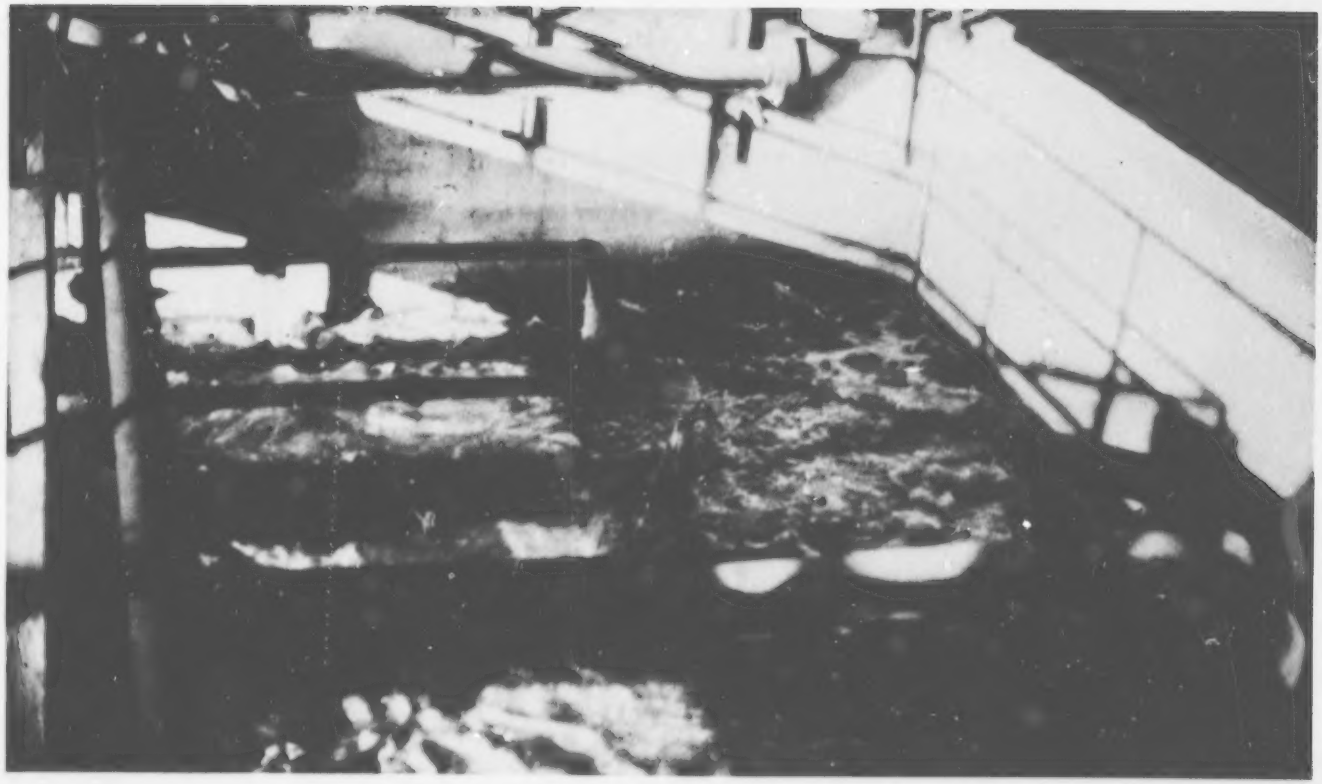

Figure D-5. Pre-aeration primary unit and composite sampler.

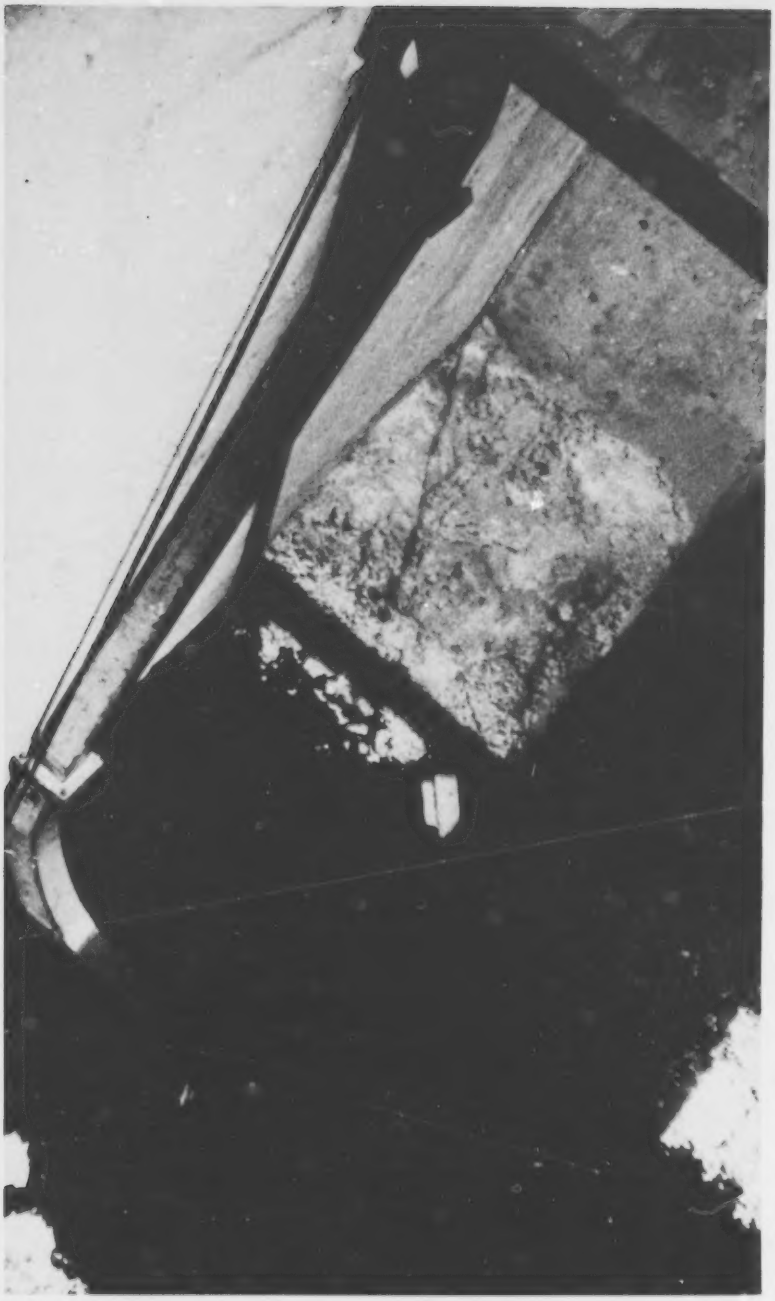

Figure D-6. Tubular conveyors in primary system.

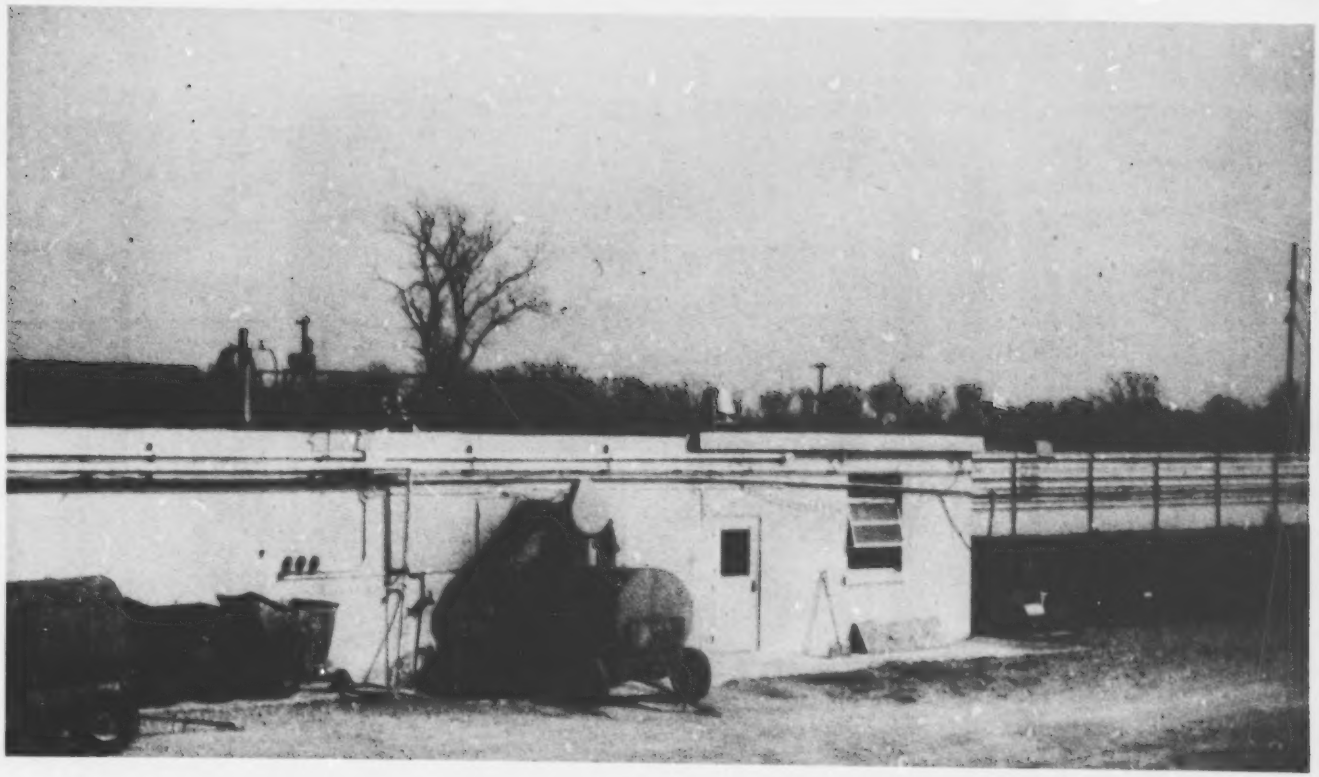

Figure D-7. Grease wagons and solids disposal carts.

Figure D-8. Rotor and floating aerators in west channel.

Figure D-9. Fifty-horsepower floating aerator.

Figure D-10. Drum failure of 50-horsepower floating aerator.

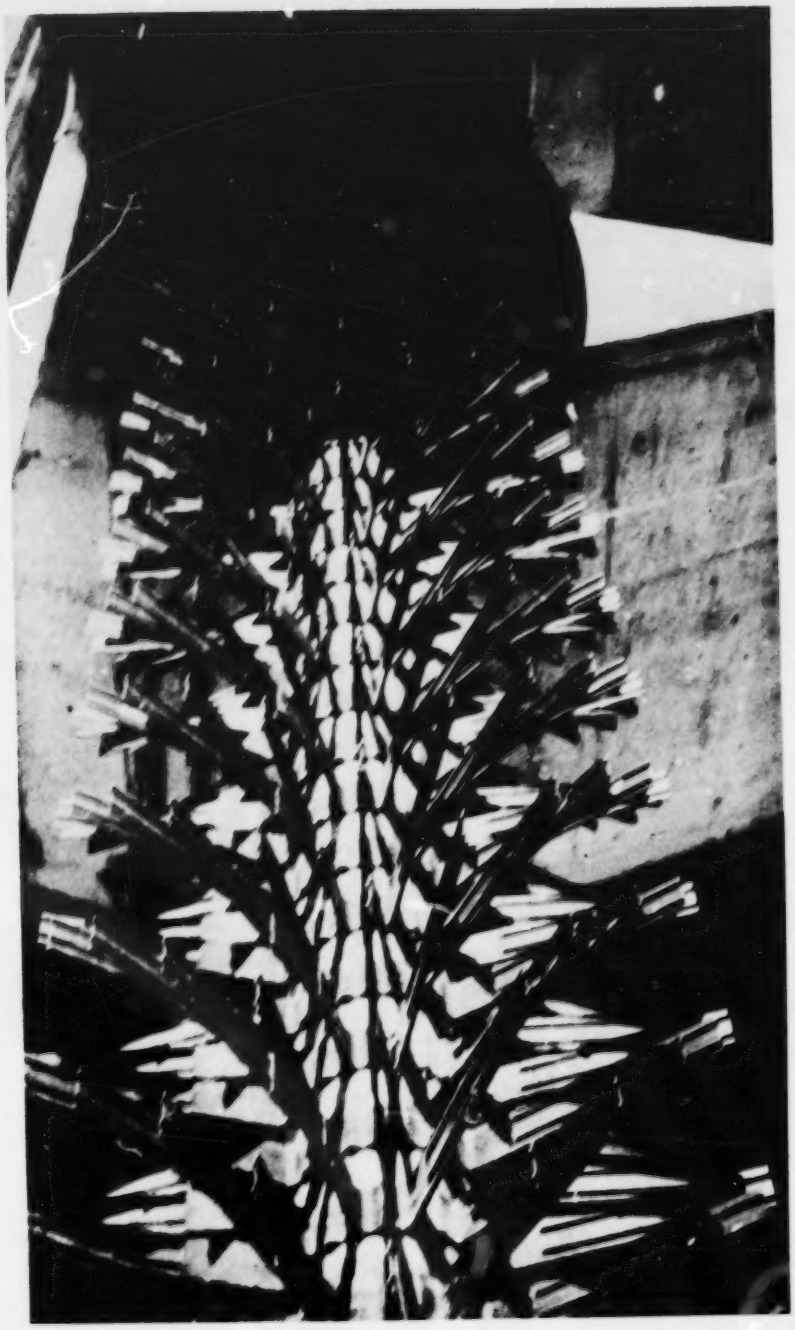

Figure D-11. Typical blades of rotor aerator.

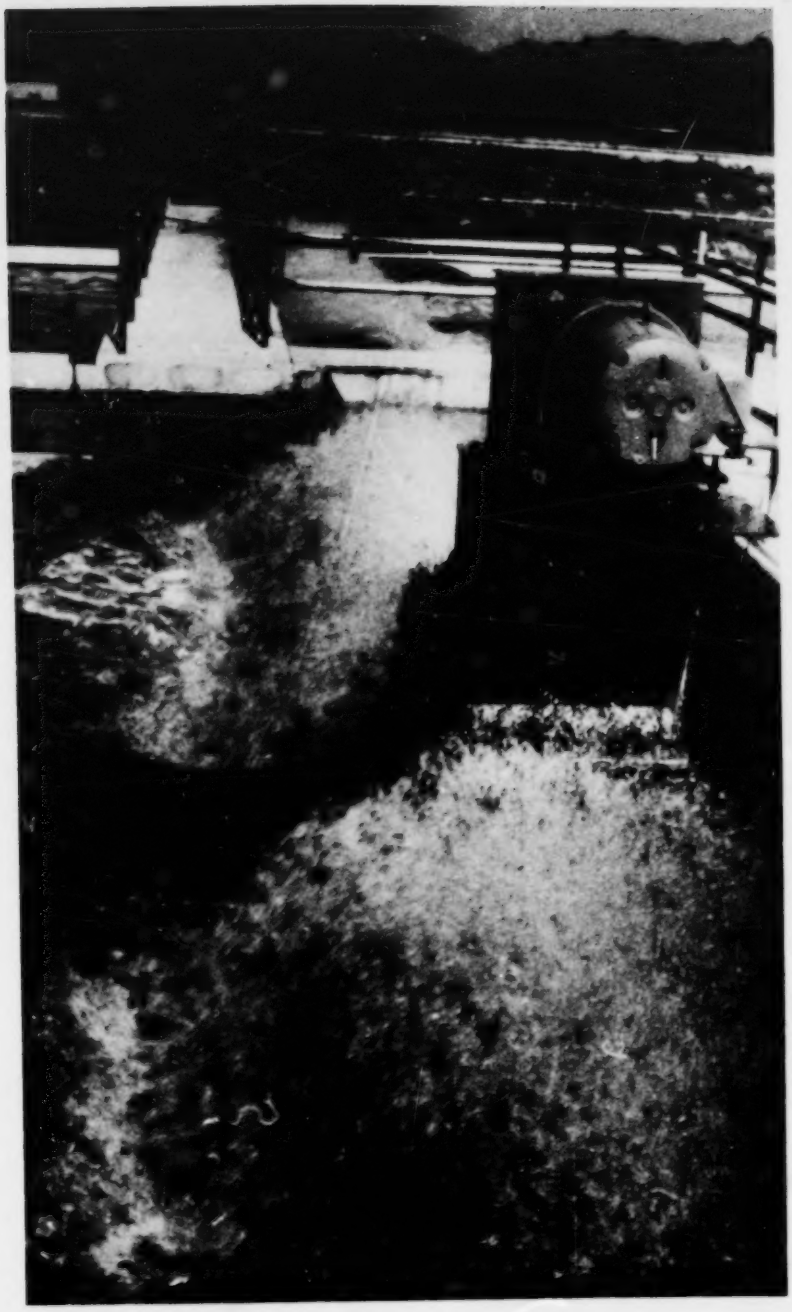

Figure D-12. Close-up of rotor aerator operation - east channel.

Figure D-13. Icing problems with rotor aerators and walkway.

Figure D-14. Initial flat shield design for icing conditions.

Figure D-15. Icing problems and motor covers - rotor aerators.

Figure D-16. Curved shield system to minimize icing.

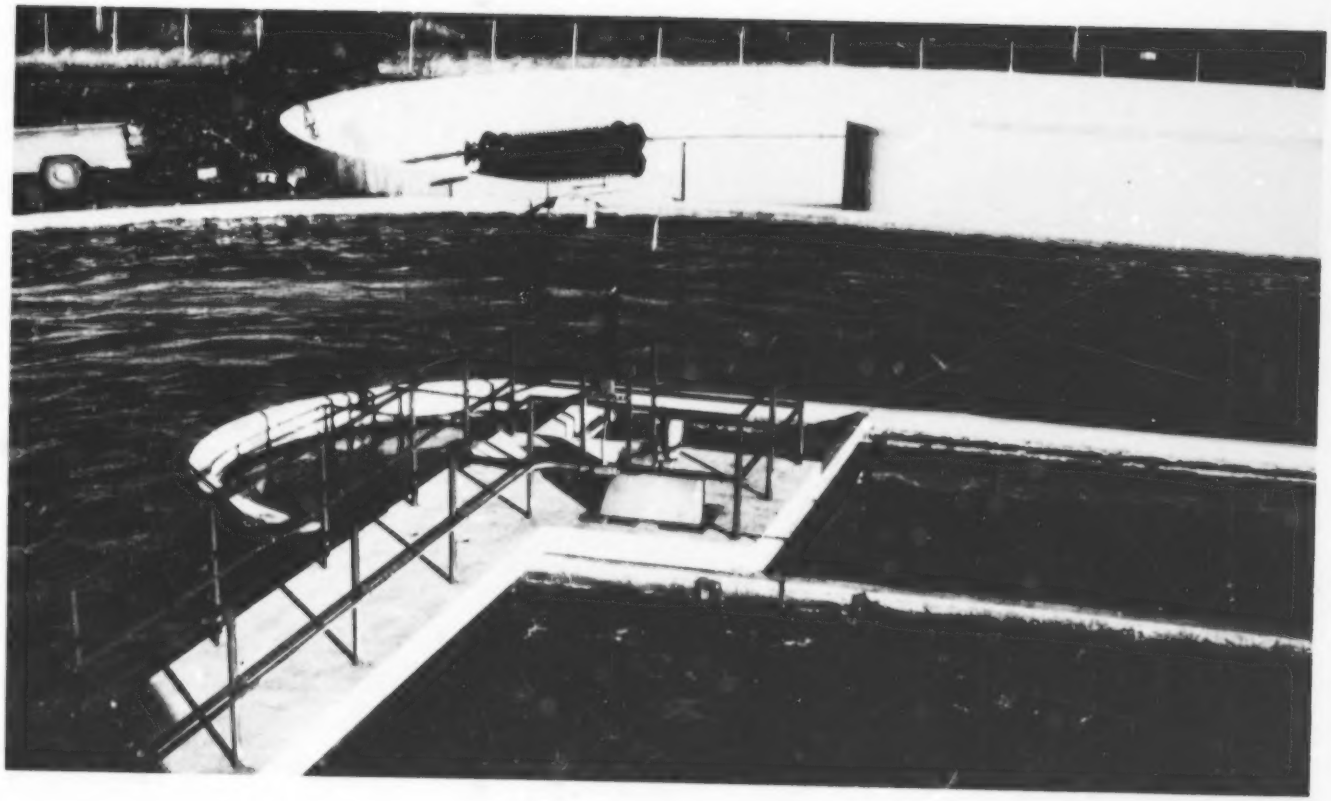

Figure D-17. Inlet and sludge collector area for straightline settler.

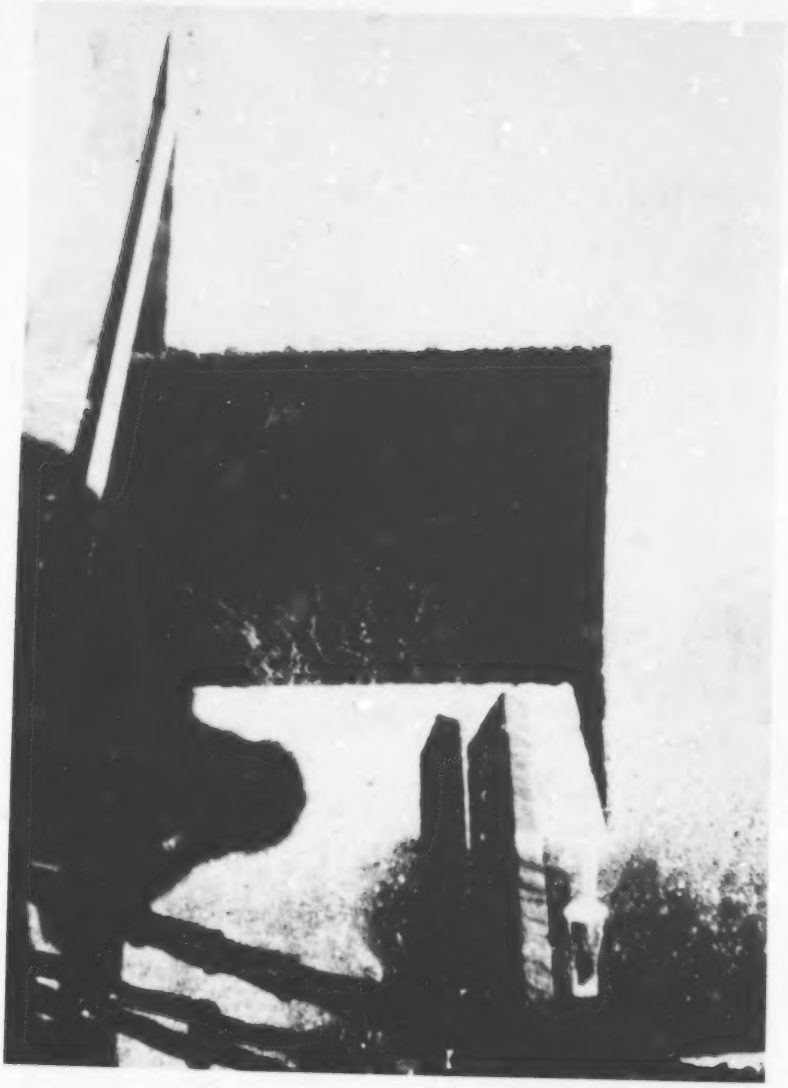

Figure D-18. Side inlet port to straightline settler.

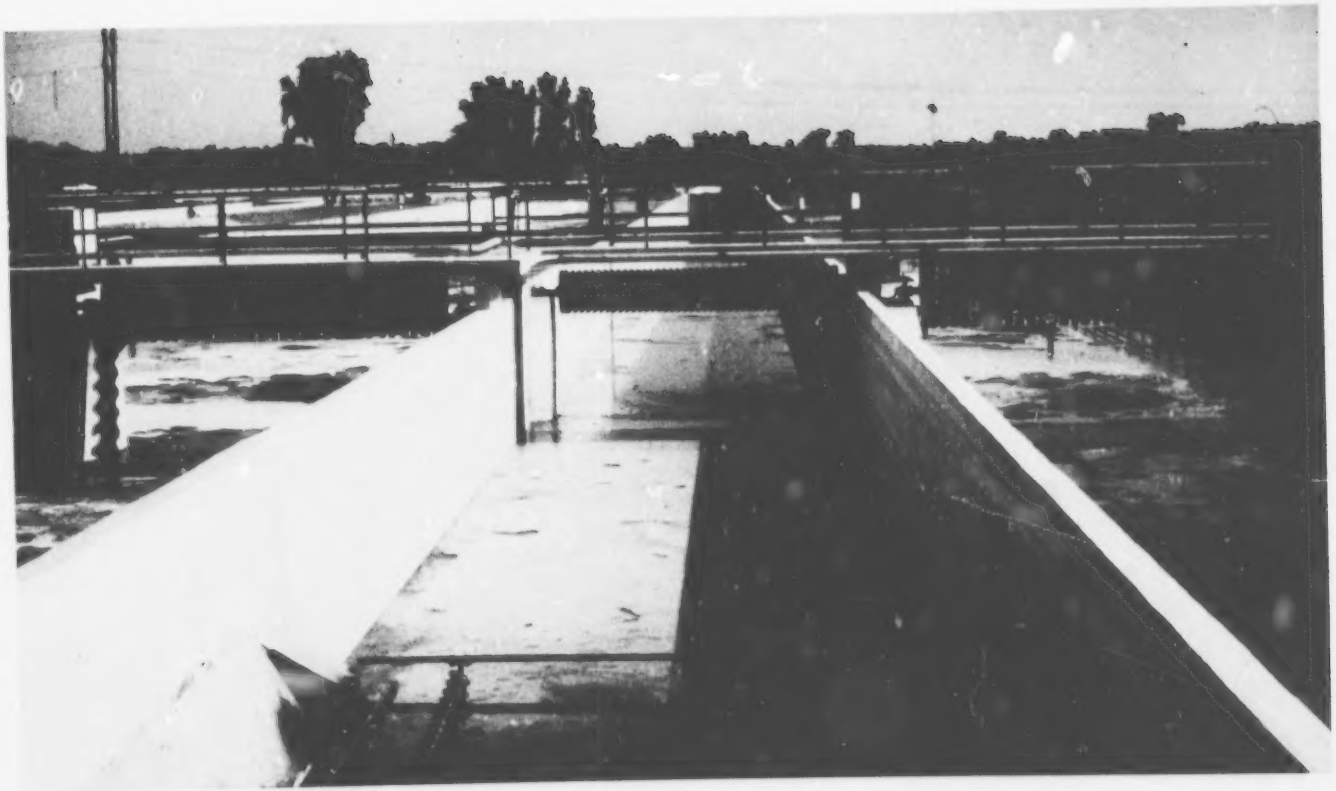

Figure D-19. Straightline settler and cage rotor - drained.

Figure D-20. Straightline settler in operation.

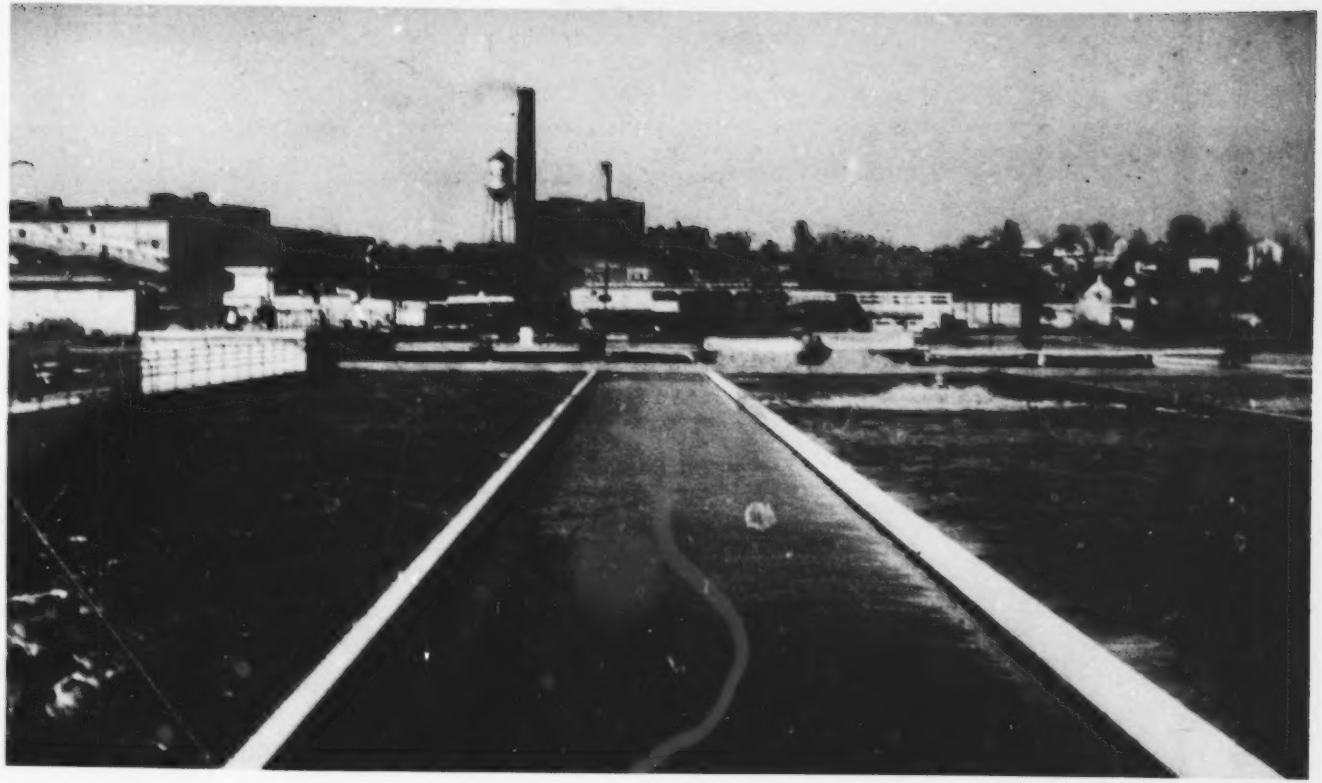

Figure D-21. Effluent weir for straightline settler.

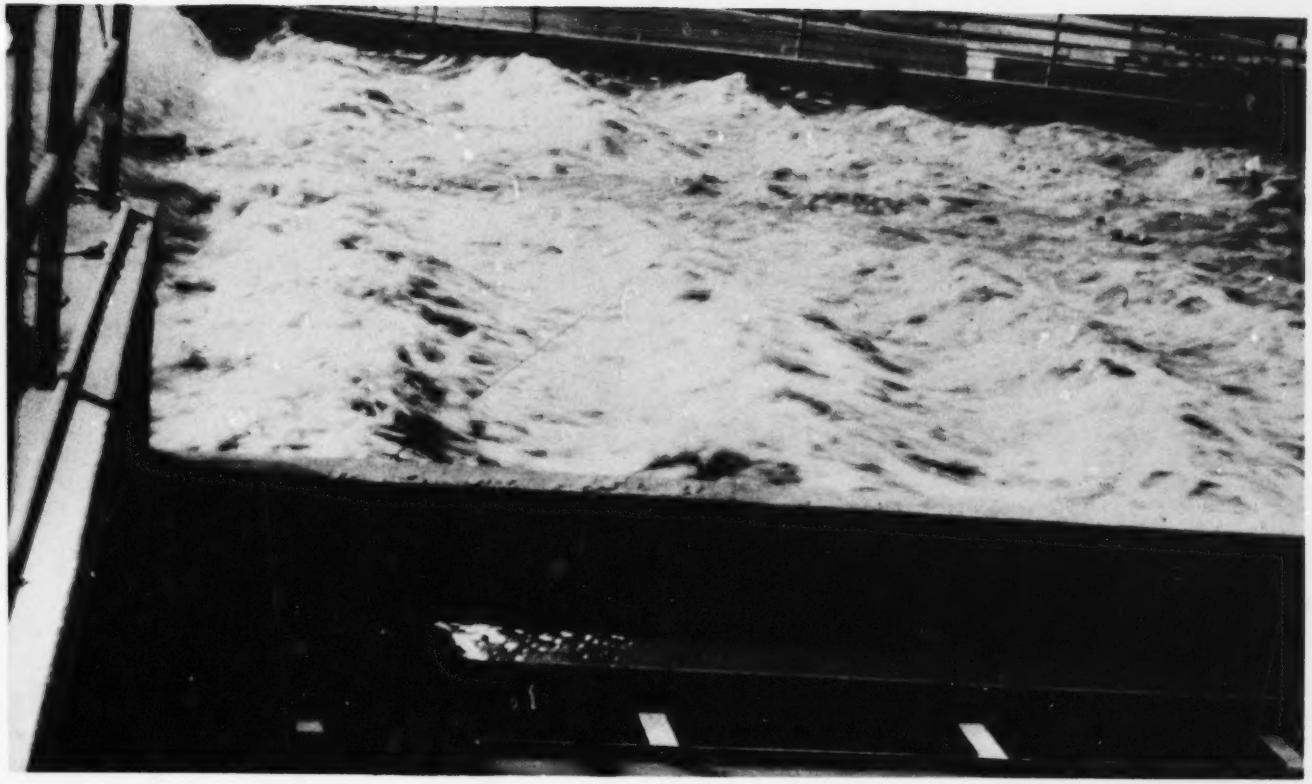

Figure D-22. Turbulence and flushing door location - straightline settler.

Figure D-23. Circular settling unit - east channel.